FARMERS' BULLETIN 1060
UNITED STATES DEPARTMENT OF AGRICULTURE

ONION DISEASES AND THEIR CONTROL

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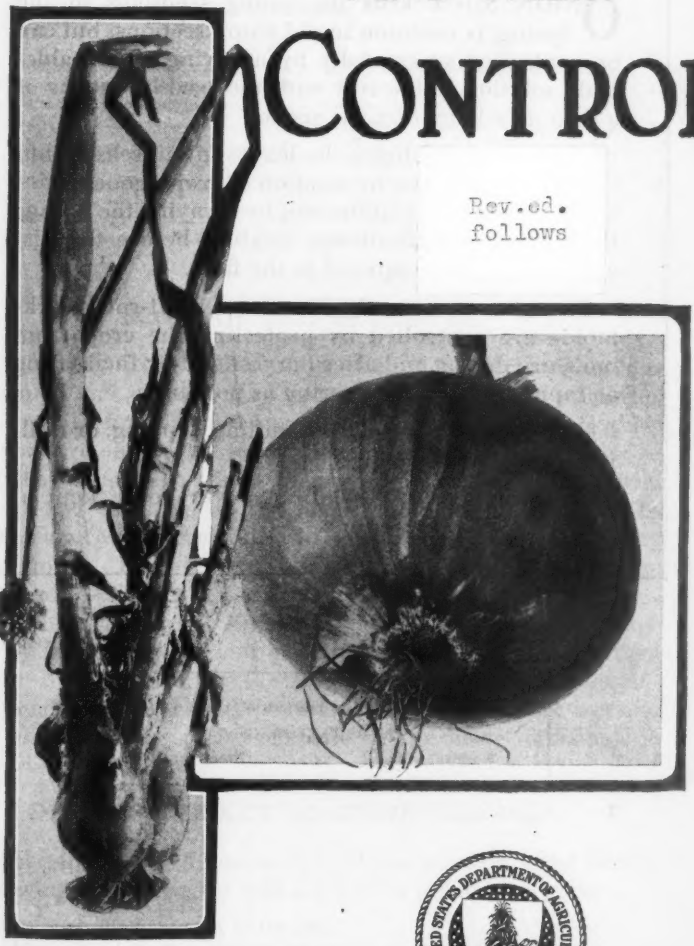

ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Storage rots—smudge, neck-rot, soft-rot, black-mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief
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ONION DISEASES AND THEIR CONTROL.

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SCOPE OF THIS BULLETIN.

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the souhern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference will be made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES.

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition.

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black, powdery masses, principally on the young seedlings. (See fig. 1)----Smut, page 4

A. Diseases primarily important in the field—Continued.

2. The leaves turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later. (See fig. 5)—Mildew, page 9

3. A black, moldy growth on leaf tips or seed stalks, often following mildew—Leaf-mold, page 12

4. A rapid dying back from the tips of the leaves, accompanied by rotting from the base of the bulb. (See fig. 6)—Fusarium rot, page 13

5. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant—Pink-root, page 13

6. The leaves become a sickly green; swellings form on the roots. (See fig. 7)—Root-knot, page 14

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard, black kernels later appear on the surface of affected scales. (See figs. 8 and 9)—Neck-rot, page 18

2. A rot begins at harvest time or later, but differs from neck-rot in that it is softer and more watery, usually with a very offensive odor. (See fig. 10)—Soft-rot, page 20

3. A semiwatery rot advancing from the base of the scale upward. (See fig. 6)—Fusarium rot, page 13

4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of or between the scales. (See fig. 11)—Black-mold, page 21

5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvest time on the outer scales; primarily on white varieties. (See fig. 12)—Smudge, page 22

In addition to these specific diseases there are certain other troubles, due to insects, with which they are liable to be confused.

(1) Thrips injury: Small, white, chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD.

SMUT.

Onion smut appeared in the United States nearly 50 years ago, when it was found to be doing damage in the Connecticut River valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. When once introduced, it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

CHARACTERISTICS OF SMUT.

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves,

the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a powdery black mass of spores in the interior of the blister (fig. 1). Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop. A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are thrown out at harvest time, occasional ones are of sufficient size to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules most prevalent near the base of the bulbs and usually occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

FIG. 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses.

CAUSE OF SMUT.

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black, powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which serve to propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating, the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage.

After the plants are about 3 inches high they become immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infected soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who are not troubled with the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT.

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible

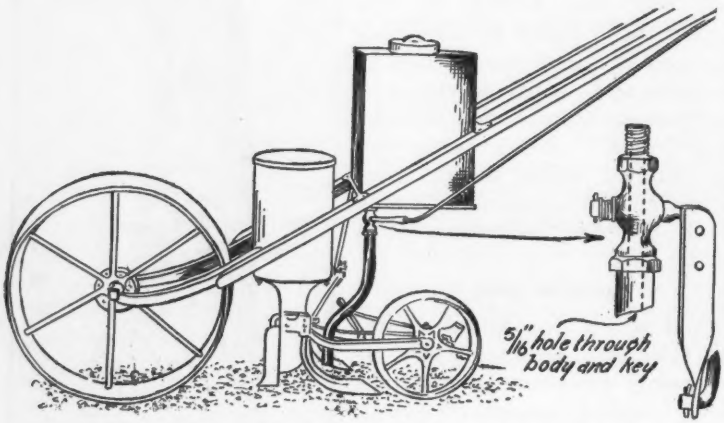

FIG. 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description.)

the returning of infected onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners have to some extent practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the Northern States, where the use of sets or seedlings is

FIG. 3.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand.

impracticable, advantage is taken of the fact that onion smut can be controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to the furrow (fig. 2). It can be made by any tinner. Such an attachment is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary

single-row seeder a 2-gallon tank is a sufficient load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of the seeder, thus enabling the operator to shut off the flow quickly at the end of the row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 8-row gang seeder.

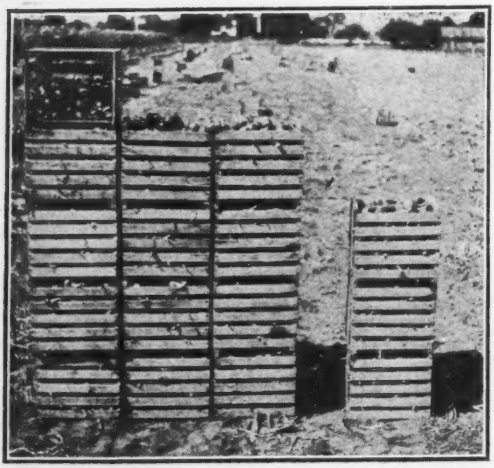

FIG. 4.—Yield of a treated and an untreated row of onions in the field shown in figure 3. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre.

Strength and quantity of the solution.—Great care should be used in applying this treatment, since too strong a formaldehyde solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 1 fluid ounce of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 200 gallons per acre, or 1 gallon to about 185 feet of row.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased

[1] For larger quantities, 1 pint to 16 gallons gives the same dilution.

in wholesale quantities, can be secured at about 25 cents per pound (1919 prices). When a single-row seeder is used, the amount of labor required at the time of sowing is about doubled, bringing the entire cost of application to about $5 per acre. (See figs. 3 and 4.)

MILDEW (BLIGHT).

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the color of the leaves becomes pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse (fig. 5). The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and partially recover. However, on the return of damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the plants, reduces growth, and the bulbs remain small.

FIG. 5.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station.)

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy

mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

CAUSE OF MILDEW.

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, the most important among which are late-blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear abundant spores. These spores are very light and are easily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt spore germination. The resulting fungus growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are wind borne to healthy plants, where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

CONTROL OF MILDEW.

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake these and burn them in the fall. Thorough cultivation is essential, in order to keep the crop as vigorous as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be con-

sidered in a rotation, especially when the general benefits of a three or four year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided. Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fishoil soap should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE.[1]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds.
Quicklime	4 pounds.
Rosin-fishoil soap	3 pounds.
Water to make	50 gallons.

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solution and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fishoil soap in a barrel and slowly add water to make 37½ gallons, *stirring constantly to avoid the formation of lumps.* These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

[1] The section on Bordeaux mixture was prepared by Mr. W. B. Clark.

Provide two 50-gallon barrels with one head removed from each and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates, mixing in the trough before entering the spray tank. While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fishoil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well distributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

LEAF-MOLD.

In midseason or later dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a weakly parasitic fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, independently or following the mildew.

Although of widespread occurrence, the actual loss due to leaf-mold is of minor importance, with the possible exception of the injury to the seed crops of Louisiana and California. There, in con-

junction with the mildew, it may cause severe damage. However, no satisfactory method of control has been perfected.

FUSARIUM ROT.

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is commonly associated with the Fusarium rot affecting the bulb. (See fig. 6.)

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scales upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Wisconsin, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury.

Strict attention to sanitary measures as outlined later (see p. 16) and careful sorting out of diseased bulbs at harvest time are the chief measures to be taken for the control of Fusarium rot.

FIG. 6.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit.

PINK-ROOT.

In the Bermuda onion regions of southern Texas pink-root is the most serious disease confronting the grower. The symptoms become manifest in the seed bed or after transplanting by the roots turning pink in color, after which they shrivel and die. As the plant

sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants seldom are killed by the disease, the reduced nourishment results in merely scallions or small bulbs being formed. Pink-root becomes the more destructive the longer onions are grown on the same field. It is caused by a soil fungus (*Fusarium malli*), which is carried over from year to year in the soil.

The disease is being investigated at present by the Texas Agricultural Experiment Station, and recommendations for its control must await the results of these studies.

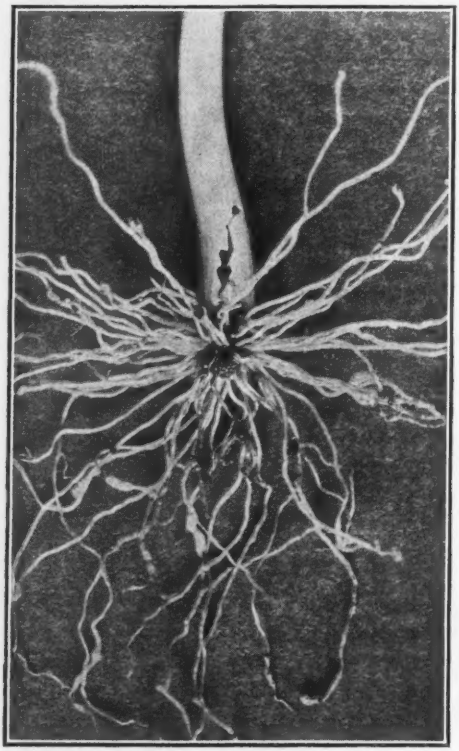

FIG. 7.—Onion root-knot, caused by an eelworm. Note that certain roots contain spherical swellings, from some of which small, dark masses (the eggs) are protruding. Many active larvæ of the eelworm escape from these egg masses into the soil, and render it unfit for growing onions as well as many other crops.

ROOT-KNOT.[1]

Root-knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in figure 7. The aboveground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color, and the bulbs are reduced in size. Root-knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Heterodera radicicola*), which lives in the soil and penetrates the onion roots, where swellings are produced. After reaching maturity in the roots, the nematode may lay hundreds

[1] The section on root-knot was prepared by Dr. L. P. Byars.

of eggs, which hatch into active forms (larvæ) and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where steaming may not be practicable, the number of nematodes can be reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

To avoid root-knot it is advisable never to plant onions on land that is known to be infested.

For further details regarding the control of root-knot, see Farmers' Bulletin 648.

FARM PRACTICE IN RELATION TO STORAGE DISEASES.

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. It should be remembered that the plant at this time has practically terminated its growth, and that on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While going into dormancy the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains warm and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck-rot (see p. 18) and soft-rot (see p. 20), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION.

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck-rot (see p. 18), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not to be used for the growing of onions.

HARVESTING.[1]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before harvesting, since this will help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of "scallions" or "stiffnecks." These should not be placed in storage, but sorted out and sold as soon as possible. In such event the cutting of the roots with a wheel hoe will tend to hasten maturity. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS.

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although smut (see p. 4) and mildew (see p. 9) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby

[1] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, "Onion Culture."

made more susceptible to the invasion of storage-rot organisms. Fusarium rot (see p. 13), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft-rot and neck-rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING.

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties (see p. 18) to damp weather in the field will almost invariably prove fatal, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING.

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls consisting of a number of thicknesses of lumber and one to several air spaces. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals are satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

RELATION OF VARIETIES TO STORAGE DISEASES.

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck-rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared

with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion regions of Texas, southern California, and Louisiana, the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT.

NECK-ROT.

Neck-rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

CHARACTERISTICS OF NECK-ROT.

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scale starts usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, which takes on a sunken, water-soaked appearance. A gray feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 8 and 9). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissue sometimes assumes a pinkish tint. The disease progresses rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties decay most readily, while the colored types more often escape it and when infected show a marked resistance to its progress.

CAUSE OF NECK-ROT.

Neck-rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi

are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs, where they germinate and send fungous threads into the necks which have been wounded by the cutting or twisting of the tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black, kernel-like bodies, or sclerotia, are compact masses of fungous threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

FIG. 8.—Onion neck-rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black, kernellike masses on the surface.

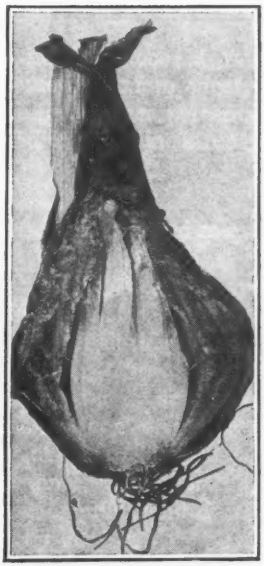

FIG. 9.—Onion neck-rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted while the disease is just appearing on the inner scales.

CONTROL OF NECK-ROT.

Proper care of the crop during harvest and curing is the chief measure of control for neck-rot (see p. 17). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation (see p. 16) is also very important and worthy of careful consideration in connection with this disease.

ARTIFICIAL CURING FOR THE CONTROL OF NECK-ROT.

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck-rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thoroughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° F. with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

FIG. 10.—A section of an onion bulb showing bacterial soft-rot. This is a watery soft-rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact.

Experiments are under way with the object of devising the best methods for the application of this principle on a commercial basis.

SOFT-ROT.

Soft-rot being of bacterial origin differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes glassy or watersoaked in appearance, and later disintegrates into a soft, watery mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. When the rot affects only one or two inner scales, as is often the case (fig. 10), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to

careless handling are followed very often by soft-rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT-ROT.

Soft-rot is due to a group of bacteria[1] which cause soft rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

CONTROL OF SOFT-ROT.

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary measures already recommended (see pp. 16 and 17) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

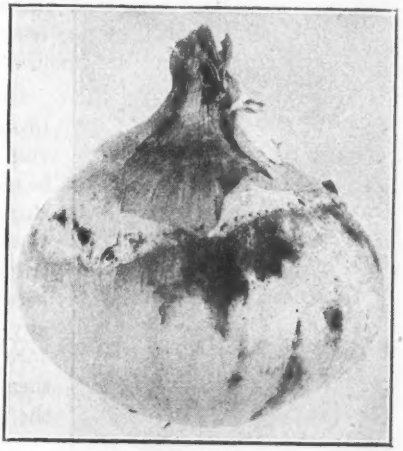

FIG. 11.—Onion black-mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle, papery texture.

BLACK-MOLD.

Because of its resemblance in appearance, black-mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic between the two is the fact that the black powdery masses of spores in the case of black-mold are borne on the exterior of the scales and can be rubbed off readily (fig. 11). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black-mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it.

Black-mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and

[1] *Bacillus carotovorus* is an example of this group.

California, however, it is the most important storage and transit disease.

CAUSE OF BLACK-MOLD.

Black-mold is caused by a fungus (*Asperillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions, it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection, which continues to develop in storage or transit.

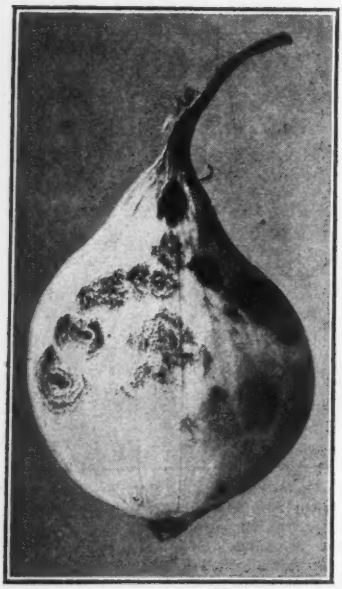

FIG. 12.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined largely to the outer scales of white varieties.

CONTROL OF BLACK-MOLD.

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be thoroughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

SMUDGE (ANTHRACNOSE, BLACK-SPOT).

Onion smudge is confined largely to white varieties and appears in the field just before harvest time, often continuing to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 12). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE.

Smudge is caused by a fungus (*Colletotrichum* (*Vermicularia*) *circinans*), which lives over winter on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (fig. 12). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather come during harvest or while the crates are stacked in the field.

CONTROL OF SMUDGE.

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain, if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

SUMMARY OF CONTROL MEASURES.

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced it should be done early and thoroughly.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry, well-ventilated warehouse at 32° to 35° F.

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UNITED STATES DEPARTMENT OF AGRICULTURE

ONION DISEASES AND THEIR CONTROL

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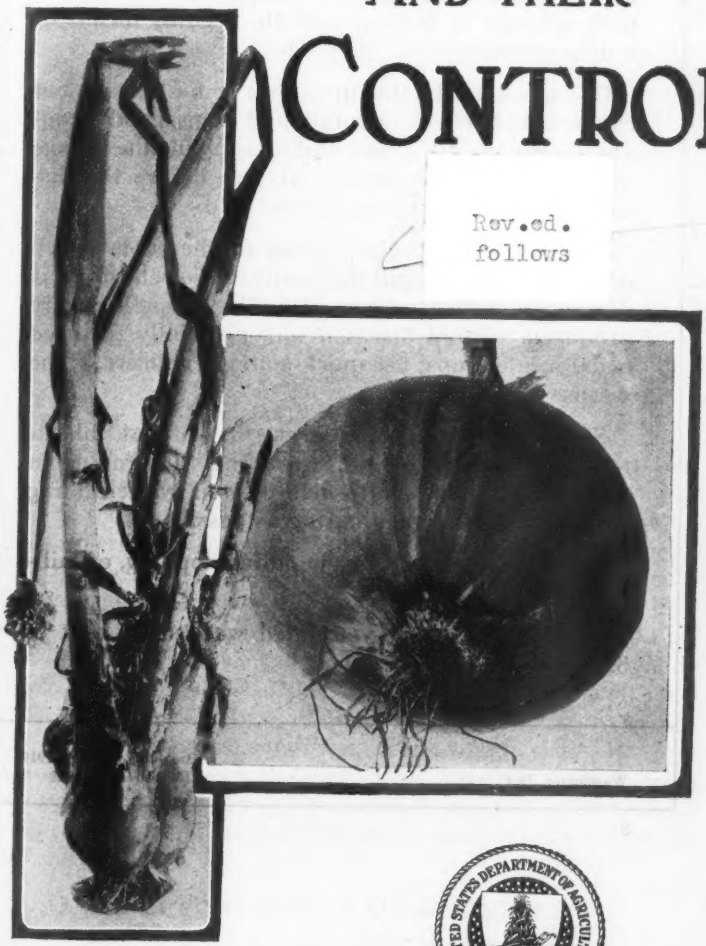

ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Pink-root is a gradual decay of the roots which does not ordinarily kill the plants but so retards their development that only small bulbs or scallions are produced. Avoid diseased soil, especially for seed beds; rotate crops; use quick-acting fertilizers, if the disease appears.

Storage rots—smudge, neck-rot, soft-rot, black-mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

Washington, D. C.

Issued November, 1919
Revised June, 1922

ONION DISEASES AND THEIR CONTROL.

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SCOPE OF THIS BULLETIN.

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference is made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES.

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition.

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings. (See Fig. 1)—Smut, page 5

2. The leaves turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later. (See Fig. 5)—Mildew, page 9

3. A black, moldy growth on leaf tips or seed stalks, often following mildew—Leaf-mold, page 15

4. A rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb. (See Fig. 6)—Fusarium rot, page 14

5. A condition of the tops quite similar to Fusarium rot but differing in that black, round bodies about the size of poppy seeds appear in the diseased bulb—White-rot, page 16

6. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant—Pink-root, page 13

7. Orange or golden yellow pustules appear on leaves or seed stems, especially on those of Egyptian onion—Rust, page 15

8. Creeping or twining, leafless, plants attack leaves of onions, often killing the tops in roughly circular areas in the field. (See Fig. 7)—Dodder, page 17

9. The leaves become a sickly green; swellings form on the roots. (See Fig. 8)—Root-knot, page 17

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard, black kernels later appear on the surface of affected scales. (See Figs. 9 and 10)—Neck-rot, page 22

2. A rot begins at harvest time or later, but differs from neck-rot in that it is softer and more watery, usually with a very offensive odor. (See Fig. 11)—Soft-rot, page 25

3. A semiwatery rot advancing from the base of the scale upward. (See Fig. 6)—Fusarium rot, page 14

4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of or between the scales. (See Fig. 12)—Black-mold, page 25

5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvest time on the outer scales; primarily on white varieties. (See Fig. 13)—Smudge, page 26

6. A semiwatery decay, at first deep yellow, then wine red and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture—Macrosporium rot, page 27

In addition to these specific diseases there are certain other troubles, due to insects, with which they may be confused:

(1) Thrips injury: Small white chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD.

SMUT.

Onion smut appeared in the United States nearly 50 years ago, when it was found to be doing damage in the Connecticut River Valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. It does not occur in the southern onion region. When once introduced, it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

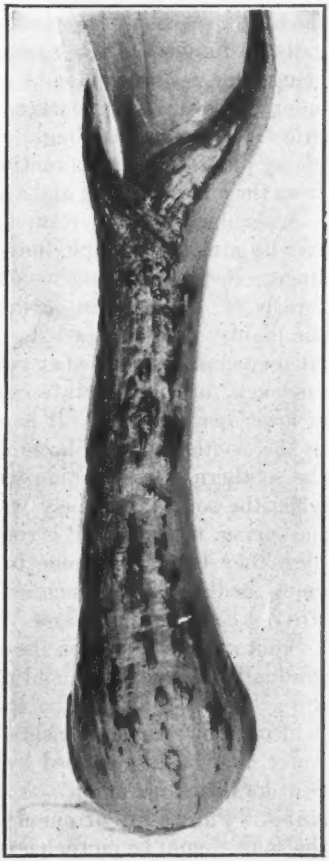

FIG. 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses.

CHARACTERISTICS OF SMUT.

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves, the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a powdery black mass of spores in the interior of the blister (Fig. 1). Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop. A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are thrown out at harvest time, occasional ones are large enough to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules, most prevalent near the base of the bulbs and usually occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly

and are more subject to the attack of other organisms than healthy ones.

CAUSE OF SMUT.

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating, the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage. Recent experiments show that when the mean soil temperature is 84° F. or above during this period no infection occurs, and the plant having escaped the fungus remains free from the disease. At temperatures somewhat below that mentioned there is a greater tendency for slightly infected plants to outgrow the disease than at lower temperatures. It is probable that the absence of the disease in the South is due in large measure to these facts, inasmuch as in the southern sections onion seed is sown in August and September, when the soil is extremely warm, while in the North it is sown in the spring, when the soil is cool. After the plants are about 3 inches high they become immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infested soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who have not been troubled with the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT.

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible the returning of infested onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it

may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners to some extent have practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the

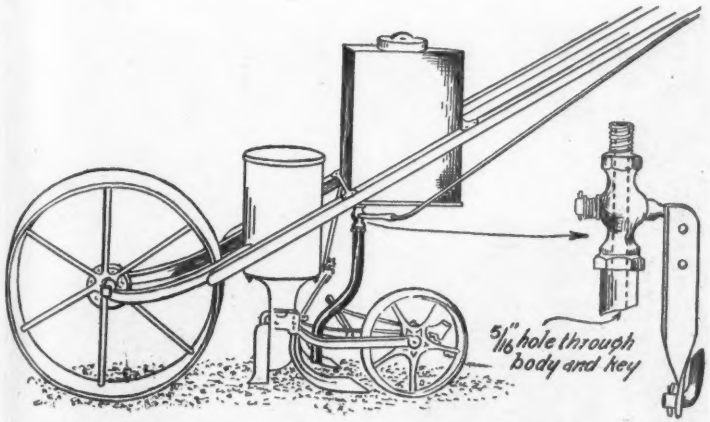

FIG. 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description.)

general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the Northern States, where the use of sets or seedlings is impracticable, onion smut is controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to the furrow (Fig. 2). It can be made by any tinner. Such an attachment

is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary single-row seeder a 2-gallon tank is a sufficient load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of

FIG. 3.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand.

the seeder, enabling the operator to shut off the flow quickly at the end of the row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 8-row gang seeder.

Strength and quantity of the solution.—Great care should be used in applying this treatment, since too strong a formaldehyde solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 1 fluid ounce of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 200 gallons per acre, or 1 gallon to about 185 feet of row.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased in wholesale quantities, can be obtained at about 8 cents a pound (1922 prices). When a single-row seeder is used, the labor required at the time of sowing is about doubled, bringing the entire cost of application to about $3 an acre. This is a very insignificant cost compared with the financial return from the operation. (See Figs. 3 and 4.)

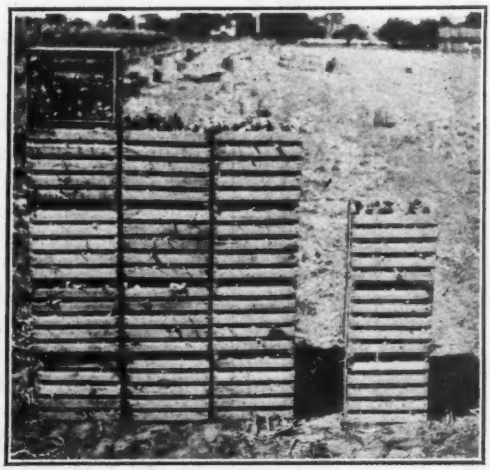

FIG. 4.—Yield of a treated and an untreated row of onions in the field shown in Figure 3. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre.

MILDEW (BLIGHT).

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the leaves become pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse (Fig. 5). The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and par-

[1] For larger quantities 1 pint to 16 gallons gives the same dilution.

tially recover. However, on the return of damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the plants, reduces growth, and the bulbs remain small.

FIG. 5.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station.)

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

CAUSE OF MILDEW.

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, among the most important of which are late-blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear an abundance of spores. These spores are very light and are easily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt germination of the spores. The resulting fungous growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are wind-borne to healthy plants, where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

CONTROL OF MILDEW.

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake these and burn them in the fall. Thorough cultivation is essential in order to keep the crop as vigorous as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be considered in a rotation, especially when the general benefits of a three or four year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided. Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fishoil soap should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be

necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE.[2]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds.
Quicklime	4 pounds.
Rosin-fishoil soap	3 pounds.
Water to make	50 gallons.

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solution and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fishoil soap in a barrel and slowly add water to make 37½ gallons, *stirring constantly to avoid the formation of lumps.* These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

Provide two 50-gallon barrels with one head removed from each and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates, mixing in the trough before entering the spray tank. While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fishoil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well dis-

[2] The section on Bordeaux mixture was prepared by Mr. W. B. Clark.

tributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

PINK-ROOT.

Pink-root is rapidly becoming one of the most serious onion diseases. Until recently it was confined in its severe form to the Bermuda onion sections of southern Texas. Its first noted appearance in the Delta region of California in 1919 was followed by very heavy crop losses in 1921. In the north, although it has been found in New York, Indiana, Illinois, Wisconsin, Iowa, and Oregon, it has not as yet become a serious factor in onion production. Whether it will in the future become more aggressive under northern conditions is an important question.

CHARACTERISTICS OF PINK-ROOT.

The symptoms become manifest in the seed bed or after transplanting. Affected roots shrivel and die and meanwhile take on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink-root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants are seldom killed by the disease, the reduced food supply results in merely scallions or small bulbs being formed. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvest time by the small size of the bulbs, varying with the severity of the attack.

CAUSE OF PINK-ROOT.

The fungus which causes pink-root (*Fusarium malli*) is closely related to the organisms associated with the Fusarium rot of the bulb scales. It lives and multiplies in the soil and consequently

becomes the more destructive the longer onions are grown in the same field. It is spread on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

CONTROL OF PINK-ROOT.

The control of pink-root is a very difficult problem when the soil once becomes infested. Diseased soil should be avoided for onion, shallot, or garlic culture. When the onion seed is sown in seed beds, clean soil should be selected. If this is not possible the soil should first be sterilized by the steam-pan method.[3] Plants should never be transplanted from a diseased seed bed to healthy soil. In sections where the disease is known to be serious a long crop rotation should be practiced.

Field experiments by the Texas Agricultural Experiment Station show that factors tending to retard the growth of the plants are very favorable to pink-root. Some relief from the disease followed the application of fertilizers which would keep the plants in a vigorously growing condition. Indications are that high soil temperature favors the disease, and, where possible, adjustment of the planting date to avoid extremely high soil temperatures is advisable.

In the North, where the disease is still of minor importance, any outbreak should be reported to the State experiment station, and onion culture on the diseased area should be abandoned for several years.

FUSARIUM ROT.

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is commonly associated with the Fusarium rot affecting the bulb. (See Fig. 6.)

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scales upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Wisconsin, Colorado, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury.

[3] For details of this method, see Farmers' Bulletin 996, entitled "Steam Sterilization of Seed Beds for Tobacco and Other Crops."

Strict attention to sanitary conditions, careful sorting out of diseased bulbs at harvest time, and rotation of crops are the chief measures to be taken for the control of Fusarium rot.

LEAF-MOLD (BLACK STALK-ROT).

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a weakly parasitic fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, independently or following the mildew.

Although of widespread occurrence, the actual loss due to leaf-mold is of minor importance, with the exception of the injury to the seed crops of Louisiana, California, and probably other sections. In this form it may cause severe damage, either independently or in conjunction with mildew. No satisfactory method of control has been perfected.

RUST.

Two distinct rusts have been noted in America upon Egyptian perennial onions (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri*, has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus rust fungus (*Puccinia asparagi*), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears on leaves and

FIG. 6.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit.

seed stems before midseason as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or æcia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of Botrytis, very similar to or identical with one of those causing neck-rot of onion (see p. 23) commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE-ROT, A EUROPEAN DISEASE.

White-rot, a disease serious on onion and garlic and of minor importance on shallot and leek, has not as yet been authentically reported in America. It is known to be widespread in the British Isles and in Italy, and perhaps occurs in other countries of Europe. This fact is brought to the attention of growers and plant pathologists at this time because large quantities of onions and garlic are being imported from Europe annually and this disease may be introduced at any time, or in fact its introduction may already have occurred. Any outbreak of disease upon onion, garlic, or closely related plants answering to the following description [4] should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture at once.

In England, white-rot first appears late in May or early in June. The first signs are those of yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus (*Sclerotium cepivorum*) which inhabits the soil and invades first the roots and later the basal portions of the bulb scales. If diseased plants are gently pulled they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungous threads, and this is most pronounced in warm, damp weather. Somewhat later this fungous mass takes on the appearance of a closely fitting weft in which are imbedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with Fusarium rot (see p. 14), but in the latter no black sclerotia are ever formed. In the later stages white-rot may be mistaken for neck-rot (see p. 22). In the latter disease black sclerotia are commonly formed. The neck-rot sclerotia, however, are several times

[4] This description of white-rot is adapted from the published accounts of two English scientists, Drs. A. D. Cotton and M. N. Owen.

larger than those of the white-rot; moreover, a gray mold is commonly associated with neck-rot, while the mold associated with the other disease is distinctly white. Neck-rot almost always appears after harvest and starts in most cases at the neck. White-rot commonly appears in midseason or earlier, and infection occurs in the roots and bases of the scales.

DODDER.

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the above-mentioned fungous parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil or are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves and its tendril-like stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue. (See Fig. 7.) After having thus become established as a parasite the dodder gets most of its food from the onion and gradually sends out its tendrils to attack near-by plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers and by the end of the season roughly circular areas of considerable size may occur, in which the onion tops have been completely killed.

Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and it is no doubt likely to occur in any onion section. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants, out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed.

ROOT-KNOT.[5]

Root-knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in Figure 8. The above-ground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color, and the bulbs are reduced in size. Root-knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and,

[5] This section on root-knot was prepared by Dr. L. P. Byars.

fortunately, there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Heterodera radicicola*), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature

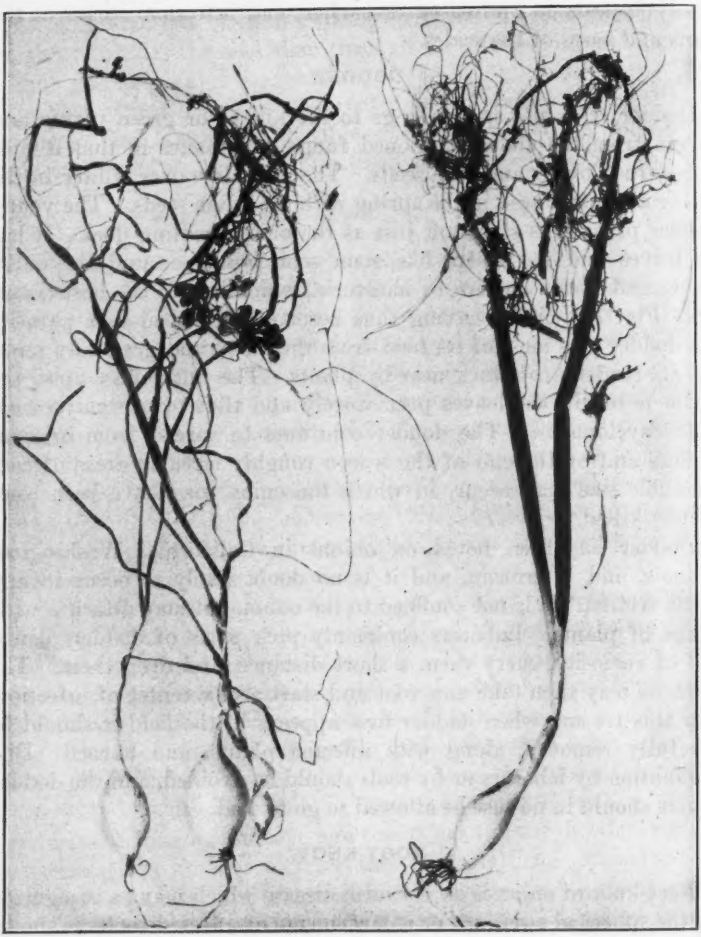

FIG. 7.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending "suckers" into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants.

in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvæ), and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where

steaming may not be practicable, the number of nematodes can be reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

To avoid root-knot it is advisable never to plant onions on land that is known to be infested.

For further details regarding the control of root-knot, see Farmers' Bulletin 648.

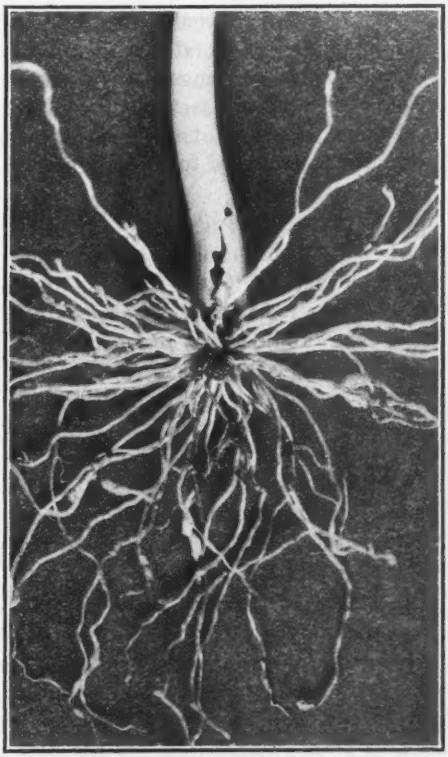

FIG. 8.—Onion root-knot, caused by an eelworm. Note that certain roots contain spherical swellings, from some of which small dark masses (the eggs) are protruding. Many active larvæ of the eelworm escape from these egg masses into the soil, and render it unfit for growing onions as well as many other crops.

FARM PRACTICE IN RELATION TO STORAGE DISEASES.

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth, and on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains clear

and dry during harvesting and curing it, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck-rot (see p. 22) and soft-rot (see p. 25), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION.

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck-rot (see p. 23), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not to be used for the growing of onions.

HARVESTING.[6]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or "stiffnecks." These should not be placed in storage, but sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops.

[6] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, "Onion Culture."

In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS.

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although smut (see p. 5) and mildew (see p. 9) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (see p. 14), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft-rot and neck-rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING.

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties (see p. 22) to damp weather in the field will almost invariably prove disastrous, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING.

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulating materials. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in

slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

RELATION OF VARIETIES TO STORAGE DISEASES.

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck-rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

FIG. 9.—Onion neck-rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black kernellike masses on the surface.

In the onion regions of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the white and yellow Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT.

NECK-ROT.

Neck-rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

CHARACTERISTICS OF NECK-ROT.

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (Figs. 9 and 10). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties decay most readily, while the colored types more often escape it and when infected show a marked resistance to its progress.

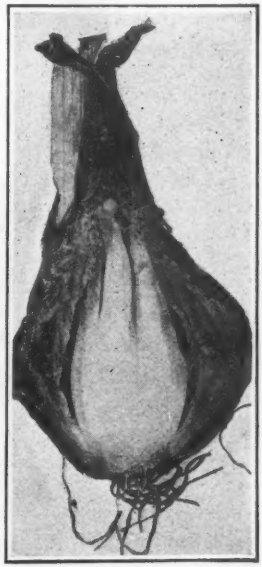

FIG. 10.—Onion neck-rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales.

CAUSE OF NECK-ROT.

Neck-rot is a disease caused by one or more species of fungi (*Bortrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs, where they germinate and send fungous threads into the necks which have been wounded by the cutting or twisting of the tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungous threads, which, being re-

sistant to cold and drought, serve to carry the organisms over winter.

CONTROL OF NECK-ROT.

Proper care of the crop during harvest and curing is the chief measure of control for neck-rot (see p. 22). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation (see p. 20) is also very important and worthy of careful consideration in connection with this disease.

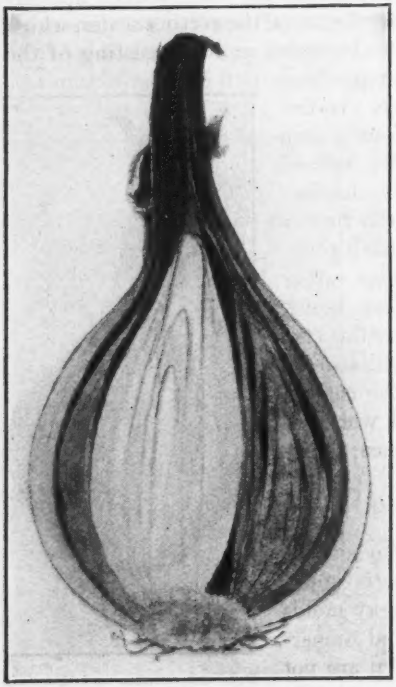

FIG. 11.—A section of an onion bulb showing bacterial soft-rot. This is a watery soft-rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact.

ARTIFICIAL CURING FOR THE CONTROL OF NECK-ROT.

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck-rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thoroughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° F. with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

Experiments are under way with the object of devising the best methods for the application of this principle on a commercial basis.

SOFT-ROT.

Soft-rot being of bacterial origin differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes glassy or watersoaked in appearance, and later disintegrates into a soft, watery mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. When the rot affects only one or two inner scales, as is often the case (Fig. 11), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to careless handling are followed very often by soft-rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT-ROT.

Soft-rot is due to a group of bacteria[7] which cause soft rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

CONTROL OF SOFT-ROT.

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary measures already recommended (see pp. 20 and 21) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

BLACK-MOLD.

Because of its resemblance in appearance, black-mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black-mold are borne on the exterior of the scales and can be rubbed off readily (Fig. 12). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black-mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it.

[7] *Bacillus carotovorus* is an example of this group.

Black-mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

CAUSE OF BLACK-MOLD.

Black-mold is caused by a fungus (*Aspergillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions, it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection, which continues to develop in storage or transit.

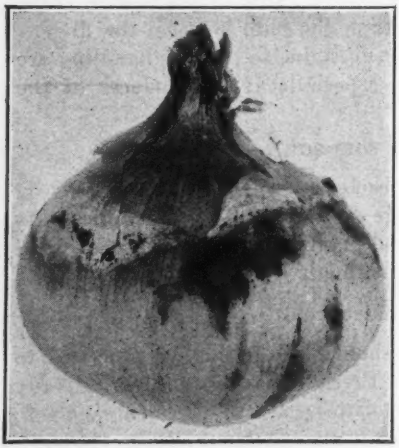

FIG. 12.—Onion black-mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle, papery texture.

CONTROL OF BLACK-MOLD.

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be thoroughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

SMUDGE (ANTHRACNOSE, BLACK-SPOT).

Onion smudge is confined largely to white varieties. It appears in the field just before harvest time and continues to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (Fig. 13). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrink-

age in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE.

Smudge is caused by a fungus (*Colletotrichum* (*Vermicularia*) *circinans*), which lives over winter on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (Fig. 13). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

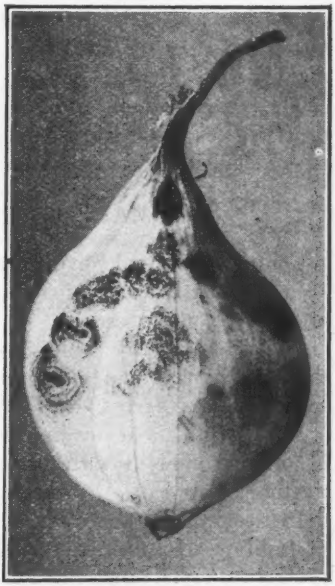

FIG. 13.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined largely to the outer scales of white varieties.

CONTROL OF SMUDGE.

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain, if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

MACROSPORIUM ROT.

White onions are occasionally affected with a decay distinct from those already described. The causal fungus is a species of Macro-

sporium, distinct, however, from that causing leaf-mold. The parasite enters most commonly through the wounded neck, but may invade other wounds on the fleshy scale. The decay is at first semiwatery in nature, but is made more noticeable by the color associated with it. The parasite secretes in abundance a pigment which is diffused through the scale tissue somewhat in advance of the fungous threads. Affected tissue is thus deep yellow at first, turning gradually to a wine red. Eventually it becomes dark brown to black, owing to the profuse development of dark-colored fungous threads in the older decayed tissue. Diseased scales later dry down to a papery texture. Often only one or two outer scales are affected. In other cases, notably those of white bottom sets, the entire bulb may be destroyed.

The causal fungus probably lives over winter in the soil. The practices described for the control of onion neck-rot (see p. 24) are recommended for this disease.

SUMMARY OF CONTROL MEASURES.

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced, it should be done early and thoroughly.

Reduce pink-root by avoiding diseased soil, especially for seed beds; rotate onions with other crops; use quick-acting fertilizers if the disease appears.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry, well-ventilated warehouse at 32° to 35° F.

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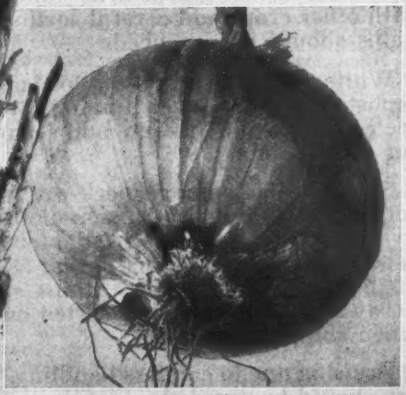
ONION DISEASES AND THEIR CONTROL



ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Pink-root is a gradual decay of the roots which does not ordinarily kill the plants but so retards their development that only small bulbs or scallions are produced. Avoid diseased soil, especially for seed beds; rotate crops; use quick-acting fertilizers, if the disease appears.

Fusarium bulb-rot appears chiefly on old soil as the soil becomes warm after midseason. Rotation with other crops and careful sorting out of decaying bulbs should be practiced.

White-rot, a disease new to America, should be reported at once when found. Steam sterilize infected areas and use no bulbs from diseased soil for propagation.

Storage rots—smudge, neck-rot, soft-rot, Fusarium rot, Macrosporium rot, black-mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible. Bulbs showing incipient decay should be carefully sorted out at harvest and when shipping.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

Washington, D. C.

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ONION DISEASES AND THEIR CONTROL

By J. C. WALKER, *Pathologist, Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry*

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SCOPE OF THIS BULLETIN

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North-Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference is made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings (see fig. 1) ---------- Smut, page 2

2. The leaves, beginning at the tips, turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later (see fig. 6) ---------- Mildew, page 5

3. A black, moldy growth on leaf tips or seed stalks, often following mildew ---- Leaf-mold, page 9

4. A rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (see fig. 7) ---------- Fusarium rot, page 8

5. A condition of the tops quite similar to Fusarium rot but differing in that black, round bodies about the size of poppy seeds appear in the diseased bulb (see fig. 8) ---- White-rot, page 10

6. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant ---------- Pink-root, page 8

7. Orange or golden yellow pustules appear on leaves or seed stems, especially on those of Egyptian onion ------ Rust, page 9

8. Creeping or twining, leafless plants attack leaves of onions, often killing the tops in roughly circular areas in the field (see fig. 9) ------- Dodder, page 12

9. The leaves become a sickly green; swellings form on the roots (see fig. 10) ---- Root-knot, page 12

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard, black kernels later appear on the surface of affected scales (see figs. 11 and 12) ---------- Neck-rot, page 14

2. A rot begins at harvest time or later, but differs from neck-rot in that it is softer and

B. Diseases primarily important in storage and transit—Continued.

more watery, usually with a very offensive odor (see fig. 13)----------Soft-rot, page 16

3. A semiwatery rot advancing from the base of the scale upward (see fig. 7)----------Fusarium rot, page 8

4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (see fig. 14)----------Black-mold, page 16

5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvest time on the outer scales; primarily on white varieties (see fig. 15)----------Smudge, page 17

6. A semiwatery decay, at first deep yellow, then wine red and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture----Macrosporium rot, page 18

In addition to these specific diseases there are certain other troubles, due to insects, with which they may be confused:

(1) Thrips injury: Small white chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes associated and confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Onion smut appeared in the United States nearly 50 years ago, when it was found to be doing damage in the Connecticut River Valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. It does not occur in the southern onion region. When once introduced it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

CHARACTERISTICS OF SMUT

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves, the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a powdery black mass of spores in the interior of the blister (fig. 1). Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop.

FIG. 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses

A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are

thrown out at harvest time, occasional ones are large enough to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules, most prevalent near the base of the bulbs and usually occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

CAUSE OF SMUT

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating, the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage. Experiments show that when the mean soil temperature is 84° F. or above during this period no infection occurs, and the plant having escaped the fungus remains free from the disease. At temperatures somewhat below that mentioned there is a greater tendency for slightly infected plants to outgrow the disease than at lower temperatures. It is probable that the absence of the disease in the South is due in large measure to these facts, inasmuch as in the southern sections onion seed is sown in August and September, when the soil is extremely warm, while in the North it is sown in the spring, when the soil is cool. After the plants are about 3 inches high they become immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infested soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who have not been troubled with the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible the returning of infested onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners to some extent have practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the Northern States, where the use of sets or seedlings is impracticable, onion smut is controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to the furrow (fig. 2). It can be made by any tinner. Such

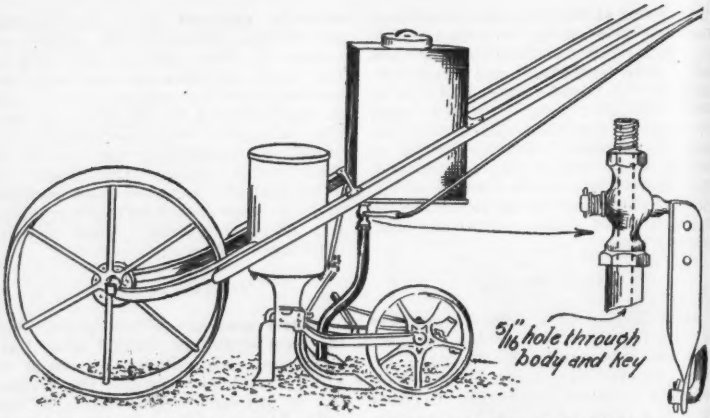

FIG. 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description)

an attachment is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary single-row seeder a 2-gallon tank is a sufficient load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of the seeder, enabling the operator to shut off the flow quickly at the end of the row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 6 or 8 row gang seeder (fig. 3).

Strength and quantity of the solution.—Great care should be used in applying

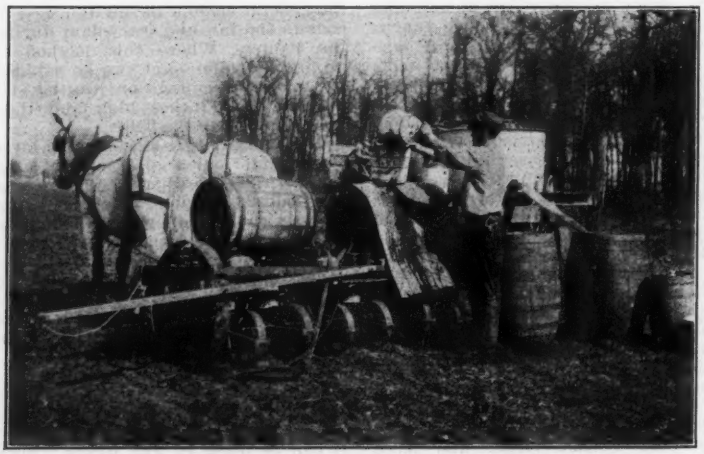

FIG. 3.—Six-row onion seeder equipped with formaldehyde drip attachment for smut control

FIG. 4.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand

this treatment, since too strong a formaldehyde solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 1 fluid ounce of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 200 gallons per acre, or 1 gallon to about 185 feet of row. In case it is not practicable to apply so large a quantity of liquid the strength may be doubled, i. e., 2 ounces of the concentrated liquid to 1 gallon of water.[2] In this instance about 100 gallons per acre will give nearly as good control as when the larger amount of more dilute disinfectant is used.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased in wholesale quantities, can be obtained at about 19 cents a pound (1925 prices). When a single-row seeder is used, the labor required at the time of sowing is about doubled, bringing the entire cost of application to about $3 an acre. This is a very insignficant cost, compared with the financial return from the operation (figs. 4 and 5).

MILDEW (BLIGHT)

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the leaves become pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse (fig. 6). The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and partially recover. However, on the return of

[1] For larger quantites 1 pint to 16 gallons gives the same dilution.
[2] 1 quart to 16 gallons of water.

damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the

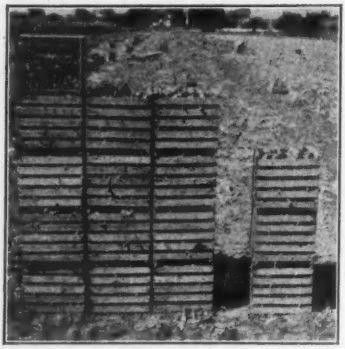

FIG. 5.—Yield of a smut treated and an untreated row of onions in the field shown in Figure 4. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre

plants, reduces growth, and the bulbs remain small.

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

CAUSE OF MILDEW

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, among the most important of which are late-blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear an abundance of spores. These spores are very light and are readily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt germination of the spores. The resulting fungous growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are borne by air currents to healthy plants where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter

FIG. 6.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station)

spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew

may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

CONTROL OF MILDEW

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake the latter and burn them in the fall. Thorough cultivation is essential in order to keep the crop in as vigorous condition as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be considered in a rotation, especially when the general benefits of a three- or four-year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included in the rotation.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided. Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fishoil soap or some other satisfactory spreader should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE[3]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds
Quicklime	4 pounds
Rosin-fishoil soap	3 pounds
Water to make	50 gallons

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solutions and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fishoil soap in a barrel and slowly add water to make 37½ gallons, *stirring constantly to avoid the formation of lumps.* These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

Provide two 50-gallon barrels each with one head removed and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates, mixing in the trough before entering the spray tank.

[3] The section on Bordeaux mixture was prepared by W. B. Clark.

While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fishoil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well distributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

PINK-ROOT

Pink-root is rapidly becoming one of the more serious onion diseases. Until recently it was confined in its severe form to the Bermuda onion sections of Southern Texas. Its first noted appearance in the Delta region of California in 1919 was followed by very heavy crop losses in 1921. In the North, although it has been found in New York, Indiana, Illinois, Wisconsin, Iowa, and Oregon, it has not as yet become a serious factor in onion production. Whether it will in the future become more aggressive under northern conditions is an important question.

CHARACTERISTICS OF PINK-ROOT

The symptoms become manifest in the seed bed or after transplanting. Affected roots shrivel and die and meanwhile take on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink-root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants are seldom killed by the disease, the reduced food supply results in mere scallions or small bulbs being formed. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvest time by the small size of the bulbs, varying with the severity of the attack.

CAUSE OF PINK-ROOT

The fungus which causes pink-root (*Fusarium malli*) is closely related to the organisms associated with the Fusarium rot of the bulb scales. It lives and multiplies in the soil and consequently becomes the more destructive the longer the onions are grown in the same field. It is spread on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

CONTROL OF PINK-ROOT

The control of pink-root is a very difficult problem when the soil once becomes infested. Diseased soil should be avoided for onion, shallot, or garlic culture. When the onion seed is sown in seed beds, clean soil should be selected. If this is not possible the soil should first be sterilized by the steam-pan method.[4] Plants should never be transplanted from a diseased seed bed to healthy soil. In sections where the disease is known to be serious a long crop rotation should be practiced.

Field experiments by the Texas Agricultural Experiment Station show that factors tending to retard the growth of the plants are very favorable to pinkroot. Some relief from the disease followed the application of fertilizers which would keep the plants in a vigorously growing condition. Indications are that high soil temperature favors the disease, and, where possible, adjustment of the planting date to avoid extremely high soil temperatures is advisable.

In the North, where the disease is still of minor importance, any outbreak should be reported to the State experiment station, and onion culture on the diseased area should be abandoned for several years.

FUSARIUM ROT

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is

[4] For details of this method, see Farmers' Bulletin 996, "Steam Sterilization of Seed Beds for Tobacco and Other Crops."

FIG. 7.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit

commonly associated with the Fusarium rot affecting the bulb (fig. 7).

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scales upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Indiana, Wisconsin, Iowa, Colorado, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury. It has been shown that certain if not all of the causal organisms are most active at comparatively high temperatures. This is probably the chief reason for its appearance after midseason in the North and for its unusual destructiveness in the Walla Walla, Wash., and Uncompahgre, Colo., districts, where very warm weather prevails for some weeks previous to harvest.

Strict attention to sanitary conditions, careful sorting out of diseased bulbs at harvest time, and rotation of crops are the chief measures to be taken for the control of Fusarium rot.

LEAF-MOLD (BLACK STALK-ROT)

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a weakly parasitic fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, independently or following the mildew.

Although of widespread occurrence, the actual loss due to leaf-mold is of minor importance, with the exception of the injury to the seed crops of Louisiana, California, and probably other sections. In this latter form it may cause severe damage, either independently or in conjunction with mildew. No satisfactory method of control has been perfected.

RUST

Two distinct rusts have been noted in America upon the Egyptian peren-

nial onion (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri*, has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus-rust fungus (*Puccinia asparagi*), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears on leaves and seed stems before midseason as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or æcia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of Botrytis, very similar to or identical with one of those causing neck-rot of onion (see p. 14) commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE-ROT, A EUROPEAN DISEASE

White-rot, a disease serious on onion, garlic, shallot, and leek, has only recently been authentically reported in northeastern Oregon and near Norfolk, Va. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain. This fact is brought to the attention of growers and plant pathologists at this time because large quantities of onions and garlic are being imported from Europe annually and this disease may be introduced again at any time. Any outbreak of the disease upon onion, garlic, or closely related plants answering to the following description should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture at once.

White-rot first appears usually during the cool moist weather in spring or autumn. The first signs are those of yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus (*Sclerotium cepivorum*) which inhabits the soil and invades the roots and the basal portions of the bulb scales (fig. 8). If diseased plants are gently pulled they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungous threads. Somewhat later this fungous mass takes on the appearance of a closely fitting weft in which are imbedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

FIG. 8. — Onion white-rot. Onion plant grown in diseased soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical, black sclerotia which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal portion of the plant the tops turn yellow and gradually die

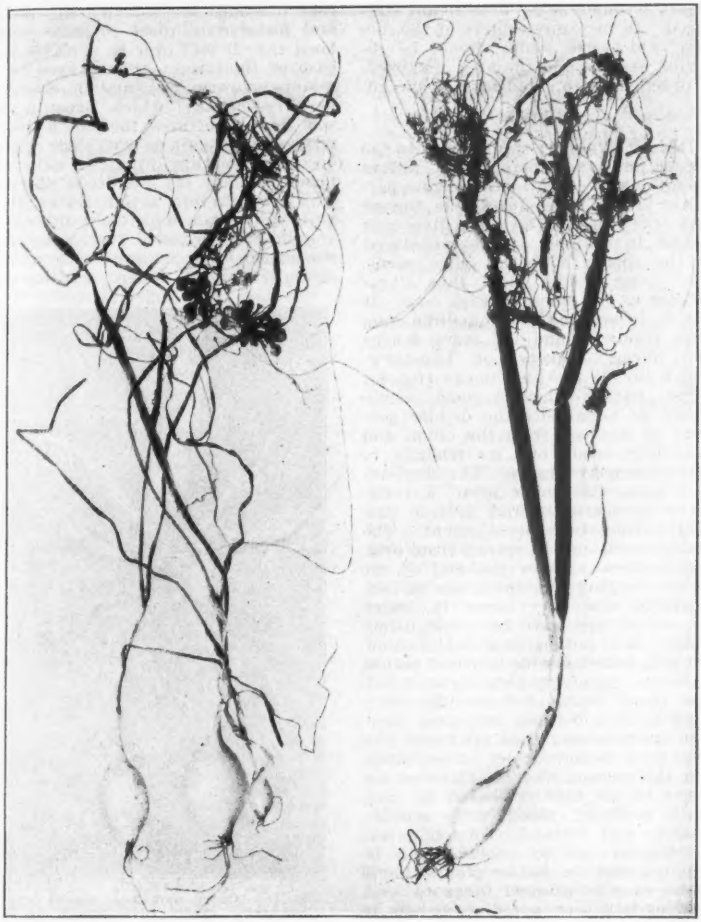

FIG. 9.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending "suckers" into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants

In the early stages this disease might easily be confused with Fusarium rot (see p. 8), but in the latter no black sclerotia are ever formed. In the later stages white-rot may be mistaken for neck-rot (see p. 14). In the latter disease black sclerotia are commonly formed. The neck-rot sclerotia, however, are several times larger than those of the white-rot; moreover, a gray mold is commonly associated with neck-rot, while the mold associated with the other disease is distinctly white. Neck-rot almost always appears after harvest and starts in most cases at the neck. White-rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The parasite is disseminated chiefly by bulbs which have come from diseased soil. Once established it may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation and soil once infected should not be used again for onions or closely related

plants without being first steam sterilized. In fact, any centers of the disease which are found should be reported at once and the area sterilized, if practicable, to avoid further spread.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the above-mentioned fungous parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil or are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue (fig. 9). After having thus become established as a parasite the dodder gets most of its food from the onion and gradually sends out its tendrils to attack near-by plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season roughly circular areas of considerable size may occur in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants, out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and it is no doubt likely to occur in any onion section.

ROOT-KNOT [5]

Root-knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in Figure 10. The aboveground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color, and the bulbs are reduced in size. Root-knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Heterodera radicicola*), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvæ), and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where steaming may not be practicable, the number of nematodes can be reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

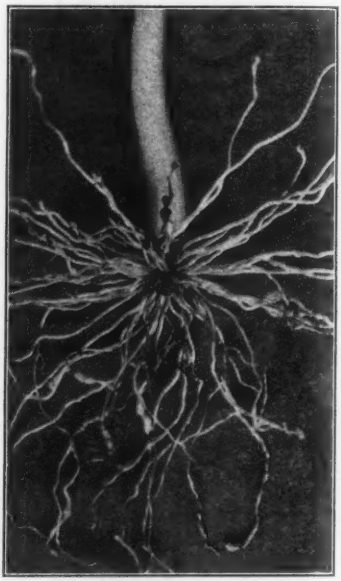

FIG. 10.—Onion root-knot, caused by an eelworm. Note that certain roots contain spherical or irregular swellings, from some of which small dark masses (the eggs) are protruding. Many active larvæ of the eelworm escape from these egg masses into the soil and render it unfit for growing onions as well as many other crops

[5] This section on root-knot was prepared by Dr. L. P. Byars.

To avoid root-knot it is advisable never to plant onions on land that is known to be infested.

For further details regarding the control of root-knot, see Farmers' Bulletin 1345.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth, and on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck-rot (see p. 14) and soft-rot (see p. 16), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck-rot (see p. 14), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for the growing of onions.

HARVESTING [6]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or "stiffnecks." These should not be placed in storage, but sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although smut (see p. 2) and mildew (see p. 5) do not of themselves cause decay, bulbs which have been attacked by these fungi are

[6] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, "Onion Culture."

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thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (see p. 8), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft-rot and neck-rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. In certain sections where intense sunlight is liable to cause sunburning or scorching of the outer scales it is essential to arrange the plants after pulling so that the bulbs are in every case covered by a layer of tops. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties to damp weather in the field will almost invariably prove disastrous, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulating materials. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck-rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion regions of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the white and yellow Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK-ROT

Neck-rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

CHARACTERISTICS OF NECK-ROT

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold,

consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 11 and 12). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless

FIG. 11.—Onion neck-rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black kernellike masses on the surface

conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties decay most readily, while the colored types more often escape it and when infected show a marked resistance to its progress.

CAUSE OF NECK-ROT

Neck-rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs, where they germinate and send fungous threads into the necks which have been wounded by the cutting or twisting of the tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungous threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

CONTROL OF NECK-ROT

Proper care of the crop during harvest and curing is the chief measure of control for neck-rot (see p. 13). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation

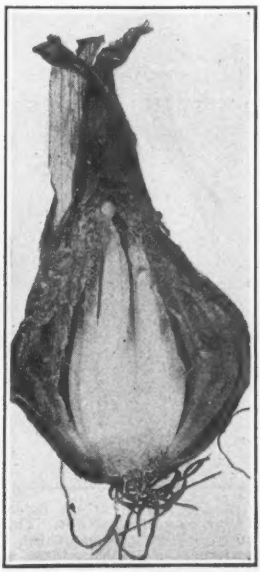

FIG. 12.—Onion neck-rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales

(see p. 13) is also very important and worthy of careful consideration in connection with this disease.

ARTIFICIAL CURING FOR THE CONTROL OF NECK-ROT

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck-rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thoroughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° F. with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

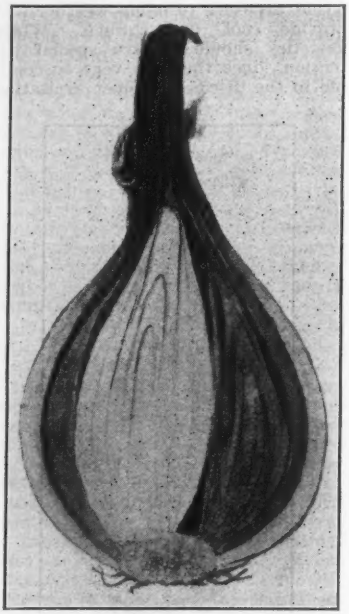

FIG. 13.—A section of an onion bulb showing bacterial soft-rot. This is a watery soft-rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact

Experiments are under way with the object ot devising the best methods for the application of this principle on a commercial basis.

SOFT-ROT

Soft-rot being of bacterial origin differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes glassy or water-soaked in appearance, and later disintegrates into a soft, watery mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. It may also enter through wounds at any point on the bulb. When the rot affects only one or two inner scales, as is often the case (fig. 13), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to careless handling are followed very often by soft-rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT-ROT

Soft-rot is due to a group of bacteria[7] which cause soft rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

CONTROL OF SOFT-ROT

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary measures already recommended (see pp. 13 and 14) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

BLACK-MOLD

Because of its resemblance in appearance, black-mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black-mold are borne on the exterior of the scales and can be rubbed off readily (fig. 14). It is true

[7] *Bacillus carotovorus* is an example of this group.

that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black-mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it.

FIG. 14.—Onion black-mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle, papery texture

Black-mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

CAUSE OF BLACK-MOLD

Black-mold is caused by a fungus (*Aspergillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions, it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection, which continues to develop in storage or transit.

CONTROL OF BLACK-MOLD

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be throughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

SMUDGE (ANTHRACNOSE, BLACK-SPOT)

Onion smudge is confined largely to white varieties. It appears in the field just before harvest time and continues to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 15). The fungus ordinarily at-

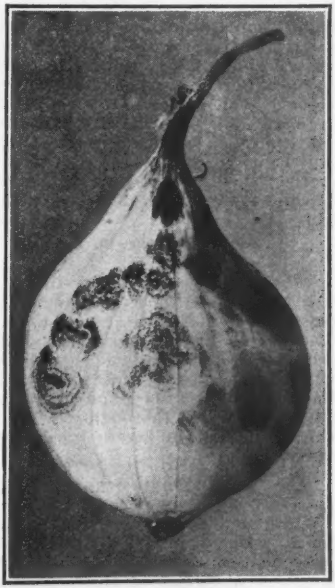

FIG. 15.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined largely to the outer scales of white varieties

tacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE

Smudge is caused by a fungus (*Colletotrichum* (*Vermicularia*) *circinans*) which lives over winter on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (fig. 15). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

CONTROL OF SMUDGE

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain, if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

MACROSPORIUM ROT

White onions are occasionally affected with a decay distinct from those already described. The causal fungus is a species of Macrosporium, distinct, however, from that causing leaf-mold. The parasite enters most commonly through the wounded neck, but may invade other wounds on the fleshy scale. The decay is at first semiwatery in nature, but is made more noticeable by the color associated with it. The parasite secretes in abundance a pigment which is diffused through the scale tissue somewhat in advance of the fungous threads. Affected tissue is thus deep yellow at first, turning gradually to a w ne red. Eventually it becomes dark brown to black, owing to the profuse development of dark-colored fungous threads in the older decayed tissue. Diseased scales later dry down to a papery texture. Often only one or two outer scales are affected. In other cases, notably those of white bottom sets, the entire bulb may be destroyed.

The causal fungus probably lives over the winter in the soil. The practices described for the control of onion neck-rot (see p. 15) are recommended for this disease.

SUMMARY OF CONTROL MEASURES

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre or 1 quart to 16 gallons at the rate of 100 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced, it should be done early and thoroughly.

Reduce pink-root by avoiding diseased soil, especially for seed beds; rotate onions with other crops; use quick-acting fertilizers if the disease appears.

Fusarium rot requires rotation with other crops or complete abandonment for a time of old onion soils. Sort out all bulbs showing any sign of disease at harvest.

White-rot is to be kept from spreading by using no bulbs from diseased soil for propagation and by steam sterilizing infected areas.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry, well-ventilated warehouse at 32° to 35° F.

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FARMERS' BULLETIN No. 1060 rev. Feb. 1928

Rev.ed. follows

ONION DISEASES AND THEIR CONTROL

XUM

ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Pink-root is a gradual decay of the roots which does not ordinarily kill the plants but so retards their development that only small bulbs or scallions are produced. Avoid diseased soil, especially for seed beds; rotate crops; use quick-acting fertilizers, if the disease appears.

Fusarium bulb-rot appears chiefly on old soil as the soil becomes warm after midseason. Rotation with other crops and careful sorting out of decaying bulbs should be practiced.

White-rot, a disease new to America, should be reported at once when found. Steam sterilize infected areas and use no bulbs from diseased soil for propagation.

Storage rots—smudge, neck-rot, soft-rot, Fusarium rot, purple blotch, black-mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible. Bulbs showing incipient decay should be carefully sorted out at harvest and when shipping.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

Washington, D. C.

Issued November, 1919
Revised February, 1928

ONION DISEASES AND THEIR CONTROL

By J. C. WALKER, *Pathologist, Office of Vegetable and Forage Diseases, Bureau of Plant Industry*

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SCOPE OF THIS BULLETIN

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North-Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference is made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings (see fig. 1)——Smut, page 2

2. The leaves, beginning at the tips, turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later (see fig. 6)——Mildew, page 5

3. A black moldy growth on leaf tips or seed stalks, often following mildew or purple blotch——Leaf-mold, page 8

4. Large purple lesions, sometimes showing zonation, eventually girdling leaves and seed stalks——Purple blotch, page 8

5. A rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (see fig. 7)——Fusarium rot, page 9

6. A condition of the tops quite similar to Fusarium rot but differing in that black round bodies about the size of poppy seeds appear in the diseased bulb (see fig. 8)——White-rot, page 10

7. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant——Pink-root, page 8

8. Orange or golden-yellow pustules appear on leaves or seed stems, especially on those of Egyptian onion——Rust, page 10

9. Creeping or twining leafless plants attack leaves of onions, often killing the tops in roughly circular areas in the field (see fig. 9)——Dodder, page 11

10. The leaves become a sickly green; swellings form on the roots (see fig. 10)——Root-knot, page 11

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard black kernels later appear on the surface of affected scales (see figs. 11 and 12)——Neck-rot, page 15

2. A rot begins at harvest time or later, but differs from neck-rot in that it is softer and

B. Diseases primarily important in storage and transit—Continued.
more watery, usually with a very offensive odor (see fig. 13)----------Soft-rot, page 16
3. A semiwatery rot advancing from the base of the scale upward (see fig. 7)----------Fusarium rot, page 9
4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (see fig. 14)----------Black-mold, page 17
5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvest time on the outer scales; primarily on white varieties (see fig. 15)----------Smudge, page 18
6. A semiwatery decay, at first deep yellow, then wine red and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture--------Purple blotch, page 8

In addition to these specific diseases there are certain other troubles, due to insects, with which they may be confused:

(1) Thrips injury: Small white chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes associated and confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Onion smut appeared in the United States some 50 years ago, when it was found to be doing damage in the Connecticut River Valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. It does not occur in the southern onion regions. When once introduced it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

CHARACTERISTICS OF SMUT

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves, the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a powdery black mass of spores in the interior of the blister. Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop (fig. 1).

FIG. 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses

A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are

thrown out at harvest time, occasional ones are large enough to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules, most prevalent near the base of the bulbs and often occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

CAUSE OF SMUT

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating, the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage. Experiments show that when the mean soil temperature is 84° F. or above during this period no infection occurs, and the plant having escaped the fungus remains free from the disease. At temperatures somewhat below that mentioned there is a greater tendency for slightly infected plants to outgrow the disease than at lower temperatures. It is probable that the absence of the disease in the South is due in large measure to these facts, inasmuch as in the southern sections onion seed is sown in August and September, when the soil is extremely warm, while in the North it is sown in the spring, when the soil is cool. After the first leaf (cotyledon) becomes mature the plant becomes immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infested soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who have not been troubled with the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible the returning of infested onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners to some extent have practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the Northern States, where the use of sets or seedlings is impracticable, onion smut is controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to the furrow (fig. 2). It can be made by any tinner. Such

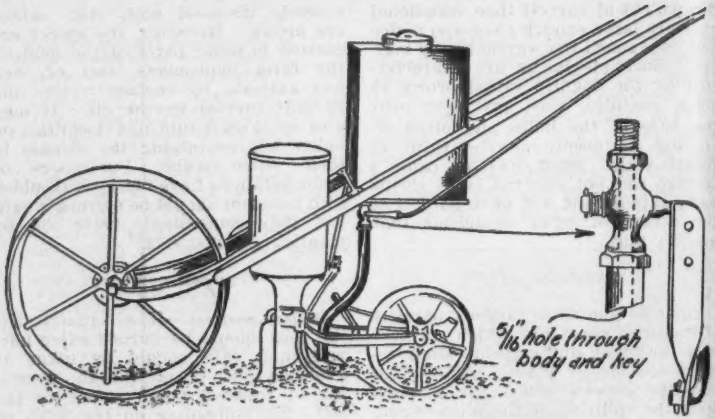

FIG. 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description)

an attachment is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary single-row seeder a 2-gallon tank is a sufficient load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of the seeder, enabling the operator to shut off the flow quickly at the end of the row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 6 or 8 row gang seeder (fig. 3) or with the garden tractor.

Strength and quantity of the solution.—Great care should be used in applying

FIG. 3.—Six-row onion seeder equipped with formaldehyde drip attachment for smut control

FIG. 4.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand

this treatment, since too strong a formaldehyde solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 2 fluid ounces of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 100 gallons per acre, or 1 gallon to about 370 feet of row.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased in wholesale quantities, can be obtained at about 19 cents a pound (1925 prices). When a single-row seeder is used, the labor required at the time of sowing is about doubled, bringing the entire cost of application to about $3 an acre. This is a very insignificant cost compared with the financial return from the operation (figs. 4 and 5).

MILDEW (BLIGHT)

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the leaves become pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse (fig. 6). The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and partially recover. However, on the return of

[1] For larger quantities 1 pint to 8 gallons gives the same dilution.

damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the

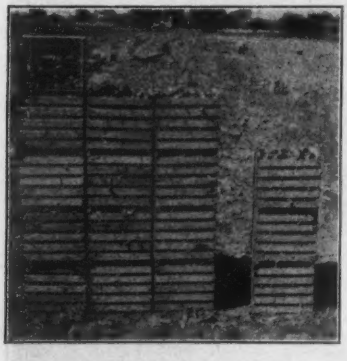

FIG. 5.—Yield of a smut treated and an untreated row of onions in the field shown in Figure 4. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre

plants, reduces growth, and the bulbs remain small.

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

CAUSE OF MILDEW

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, among the most important of which are late-blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear an abundance of spores. These spores are very light and are readily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt germination of the spores. The resulting fungous growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are borne by air currents to healthy plants where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter

FIG. 6.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station)

spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew

may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

CONTROL OF MILDEW

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake the latter and burn them in the fall. Thorough cultivation is essential in order to keep the crop in as vigorous condition as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be considered in a rotation, especially when the general benefits of a three- or four-year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included in the rotation.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided. Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fishoil soap or some other satisfactory spreader should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE[2]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds
Quicklime	4 pounds
Rosin-fishoil soap	3 pounds
Water to make	50 gallons

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solutions and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fishoil soap in a barrel and slowly add water to make 37½ gallons, *stirring constantly to avoid the formation of lumps.* These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

Provide two 50-gallon barrels each with one head removed and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates, mixing in the trough before entering the spray tank.

[2] The section on Bordeaux mixture was prepared by W. B. Clark.

While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fishoil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well distributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

LEAF-MOLD

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a secondary fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, following either the mildew or the purple blotch.

PURPLE BLOTCH

Purple blotch is another disease of leaves, seed stalks, and bulbs caused by a hitherto little-known fungus (*Macrosporium porri*). It has been commonly confused with leaf-mold because the latter often follows it as a secondary organism. The purple-blotch organism, unlike that of leaf-mold, is capable of invading the onion plant quite independently of any forerunner. The disease appears first as small, whitish, sunken lesions with purple centers which rapidly enlarge and eventually girdle the leaf or stalk. Some two or three weeks after its first appearance, darkened zones, which consist of masses of fungous spores, appear on the lesion. Usually the affected leaves or stalks fall over and die within three or four weeks. Thus appreciable damage to both the bulb and the seed crop may be experienced from this disease.

The bulbs are attacked at harvest time. The fungus enters most commonly through the wounded neck, but may invade other wounds on the fleshy scales. The decay is at first semiwatery but is made noticeable by the color associated with it. The parasite secretes in abundance a pigment which diffuses through the scale tissue somewhat in advance of the fungous threads. Affected tissue is deep yellow at first, turning gradually to a wine red. Eventually it becomes dark brown to black, owing to the profuse development of dark-colored fungous threads in the older decayed tissue. Diseased scales later dry down to a papery texture. Often only one or two outer scales are affected. In other cases, notably those of white bottom sets, the entire bulb may be destroyed.

No satisfactory control measures for the disease upon the leaves and stalks have been devised. The practices described for the control of onion neck rot (see p. 16) are recommended for the bulb rot.

PINK-ROOT

Pink-root is rapidly becoming one of the more serious onion diseases. Until recently it was confined in its severe form to the Bermuda onion sections of southern Texas. Its first noted appearance in the Delta region of California in 1919 was followed by very heavy crop losses in 1921. In the North, although it has been found in New York, Indiana, Illinois, Wisconsin, Iowa, and Oregon, it has not as yet become a serious factor in onion production. Whether it will in the future become more aggressive under northern conditions is an important question.

CHARACTERISTICS OF PINK-ROOT

The symptoms become manifest in the seed bed or after transplanting. Affected roots shrivel and die and meanwhile take on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink-root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants are seldom killed by

the disease, the reduced food supply results in mere scallions or small bulbs being formed. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvest time by the small size of the bulbs, varying with the severity of the attack.

CAUSE OF PINK-ROOT

The fungus which causes pink-root (*Fusarium malli*) is closely related to the organisms associated with the Fusarium rot of the bulb scales. It lives and multiplies in the soil and consequently becomes the more destructive the longer the onions are grown in the same field. It is spread on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

CONTROL OF PINK-ROOT

The control of pink-root is a very difficult problem when the soil once becomes infested. Diseased soil should be avoided for onion, shallot, or garlic culture. When the onion seed is sown in seed beds, clean soil should be selected. If this is not possible the soil should first be sterilized by the steam-pan method.[2] Plants should never be transplanted from a diseased seed bed to healthy soil. In sections where the disease is known to be serious a long crop rotation should be practiced.

Field experiments by the Texas Agricultural Experiment Station show that factors tending to retard the growth of the plants are very favorable to pink-root. Some relief from the disease followed the application of fertilizers which would keep the plants in a vigorously growing condition. Indications are that high soil temperature favors the disease, and, where possible, adjustment of the planting date to avoid extremely high soil temperatures is advisable.

In the North, where the disease is still of minor importance, any outbreak should be reported to the State experiment station, and onion culture on the diseased area should be abandoned for several years.

FUSARIUM ROT

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is commonly associated with the Fusarium rot affecting the bulb (fig. 7).

FIG. 7.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit

[2] For details of this method, see Farmers' Bulletin 996, "Steam Sterilization of Seed Beds for Tobacco and Other Crops."

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scales upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Indiana, Wisconsin, Iowa, Colorado, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury. It has been shown that certain if not all of the causal organisms are most active at comparatively high temperatures. This is probably the chief reason for its appearance after midseason in the North and for its unusual destructiveness in the Walla Walla, Wash., and Uncompahgre, Colo., districts, where very warm weather prevails for some weeks previous to harvest.

Strict attention to sanitary conditions, careful sorting out of diseased bulbs at harvest time, and rotation of crops are the chief measures to be taken for the control of Fusarium rot.

RUST

Two distinct rusts have been noted in America upon the Egyptian perennial onion (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri*, has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus-rust fungus (*Puccinia asparagi*), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears on leaves and seed stems before midseason as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or æcia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of Botrytis, very similar to or identical with one of those causing neck-rot of onion (see p. 15) commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE-ROT, A EUROPEAN DISEASE

White-rot, a disease serious on onion, garlic, shallot, and leek, has been reported in northeastern Oregon, near Norfolk, Va., and near Louisville, Ky. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain. This fact is brought to the attention of growers and plant pathologists at this time because large quantities of onions and garlic are being imported from Europe annually and this disease may be introduced again at any time. Any outbreak of the disease upon onion, garlic, or closely related plants answering to the following description should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture at once.

White-rot first appears usually during the cool moist weather in spring or autumn. The first signs are those of yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus (*Sclerotium cepivorum*) which inhabits the soil and invades the roots and the basal portions of the bulb scales (fig. 8). If diseased plants are gently pulled they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungous threads. Somewhat later this fungous mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with Fusarium rot (see p. 8), but in the latter no black sclerotia are ever formed. In the later stages white-rot may be mistaken for neck-rot (see p. 15). In the latter disease black sclerotia are commonly formed. The neck-rot sclerotia, however, are several times larger than those of the white-rot; moreover, a gray mold is commonly associated with neck-rot, while the mold associated with the other disease is distinctly white. Neck-rot almost always appears after harvest

and starts in most cases at the neck. White-rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The parasite is disseminated chiefly by bulbs which have come from diseased soil. Once established it may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation, and soil once infected should not be used again for onions or closely related plants without being first steam sterilized. In fact, any centers of the disease which are found should be reported at once and the area sterilized, if practicable, to avoid further spread.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the above-mentioned fungous parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil or are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue (fig. 9). After having thus become established as a parasite the dodder gets most of its food from the onion and gradually sends out its tendrils to attack near-by plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season roughly circular areas of considerable size may occur in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants, out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and it is no doubt likely to occur in any onion section.

ROOT-KNOT [4]

Root-knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in Figure 10. The aboveground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color,

FIG. 8.—Onion white-rot. Onion plant grown in diseased soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical, black sclerotia which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal portion of the plant the tops turn yellow and gradually die

and the bulbs are reduced in size. Root-knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and fortunately there is little likeli-

[4] This section on root-knot was prepared by L. P. Byars.

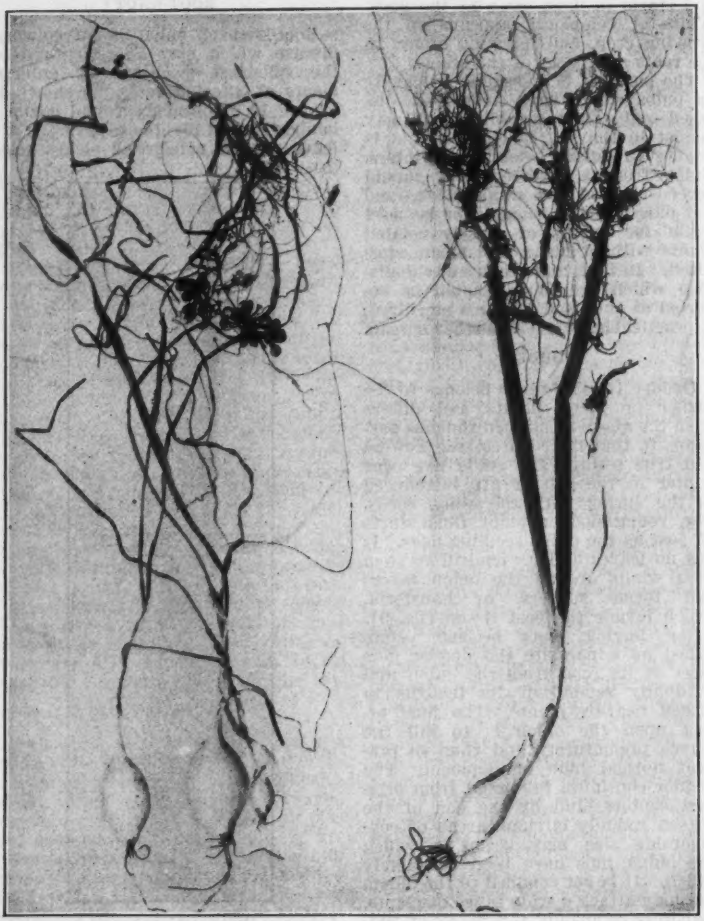

FIG. 9.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending "suckers" into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants

hood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Heterodera radicicola*), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvæ), and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where steaming may not be practicable, the number of nematodes can be reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

To avoid root-knot it is advisable never to plant onions on land that is known to be infested.

For further details regarding the control of root-knot, see Farmers' Bulletin 1345.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth, and on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck-rot (see p. 15) and soft-rot (see p. 16), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck-rot (see p. 15), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for the growing of onions.

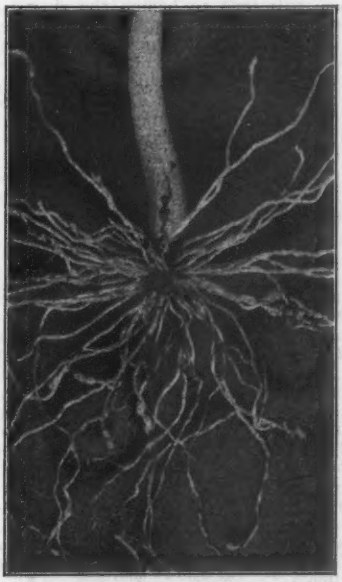

FIG. 10.—Onion root-knot, caused by an eelworm. Note that certain roots contain spherical or irregular swellings, from some of which small dark masses (the eggs) are protruding. Many active larvæ of the eelworm escape from these egg masses into the soil and render it unfit for growing onions as well as many other crops

HARVESTING[6]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will

[6] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, "Onion Culture."

help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or "stiffnecks." These should not be placed in storage, but sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although smut (see p. 2) and mildew (see p. 5) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (see p. 9), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft-rot and neck-rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. In certain sections where intense sunlight is liable to cause sunburning or scorching of the outer scales it is essential to arrange the plants after pulling so that the bulbs are in every case covered by a layer of tops. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties to damp weather in the field will almost invariably prove disastrous, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulating materials. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck-rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion regions of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the white and yellow Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK-ROT

Neck-rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially

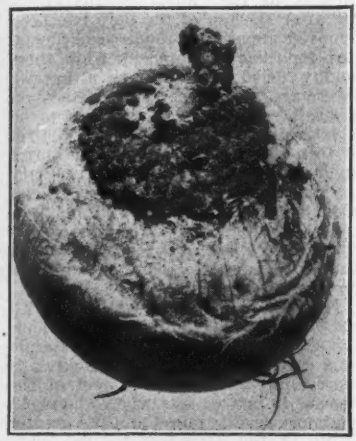

FIG. 11.—Onion neck-rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black kernellike masses on the surface

susceptible, but considerable loss is often sustained with red and yellow varieties.

CHARACTERISTICS OF NECK-ROT

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 11 and 12). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties are infected most readily, while the colored types more often escape it.

CAUSE OF NECK-ROT

Neck-rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi,

FIG. 12.—Onion neck-rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales

which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs,

where they germinate and send fungous threads into the necks either through the dead tops or through wounds left by the removal of tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernel-like bodies, or sclerotia, are compact masses of fungous threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

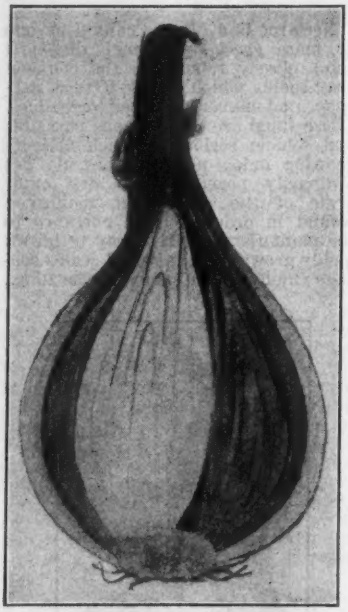

FIG. 13.—A section of an onion bulb showing bacterial soft-rot. This is a watery soft-rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact

CONTROL OF NECK-ROT

Proper care of the crop during harvest and curing is the chief measure of control for neck-rot (see p. 13). Avoid exposure to damp weather and provide cool dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation (see p. 13) is also very important and worthy of careful consideration in connection with this disease.

ARTIFICIAL CURING FOR THE CONTROL OF NECK-ROT

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck-rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thoroughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° F. with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

Experiments are under way with the object of devising the best methods for the application of this principle on a commercial basis. The method is most adaptable to the control of the disease in bottom sets where the necks are more readily cured and the greater value of the crop permits the additional expense involved.

SOFT-ROT

Soft-rot being of bacterial origin differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes glassy or water-soaked in appearance, and later disintegrates into a soft watery mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. It may also enter through wounds at any point on the bulb. When the rot affects only one or two inner scales, as is often the case (fig. 13), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to careless handling are followed very often by soft-rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT-ROT

Soft-rot is due to a group of bacteria[6] which cause soft rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

CONTROL OF SOFT-ROT

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary

FIG. 14.—Onion black-mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle papery texture

measures already recommended (see pp. 13 and 14) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

BLACK-MOLD

Because of its resemblance in appearance, black-mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black-mold are borne on the exterior of the scales and can be rubbed off readily (fig. 14). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black-mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool dry environment seems to check it.

Black-mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

CAUSE OF BLACK-MOLD

Black-mold is caused by a fungus (*Aspergillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions, it undoubtedly grows and multiplies

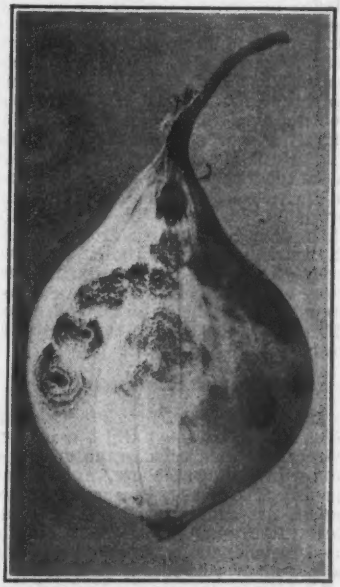

FIG. 15.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined largely to the outer scales of white varieties

throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the

[6] *Bacillus carotovorus* is an example of this group.

bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection, which continues to develop in storage or transit.

CONTROL OF BLACK-MOLD

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be throughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

SMUDGE (ANTHRACNOSE, BLACK-SPOT)

Onion smudge is confined largely to white varieties. It appears in the field just before harvest time and continues to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy unsightly appearance to the white bulbs (fig. 15). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE

Smudge is caused by a fungus (*Colletotrichum circinans*) which lives over winter on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (fig. 15). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

CONTROL OF SMUDGE

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain, if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

SUMMARY OF CONTROL MEASURES

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre or 1 quart to 16 gallons at the rate of 100 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced, it should be done early and thoroughly.

Reduce pink-root by avoiding diseased soil, especially for seed beds; rotate onions with other crops; use quick-acting fertilizers if the disease appears.

Fusarium rot requires rotation with other crops or complete abandonment for a time of old onion soils. Sort out all bulbs showing any sign of disease at harvest.

White-rot is to be kept from spreading by using no bulbs from diseased soil for propagation and by steam sterilizing infected areas.

Artificial curing is recommended for the control of neck-rot under certain circumstances.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry well-ventilated warehouse at 32° to 35° F.

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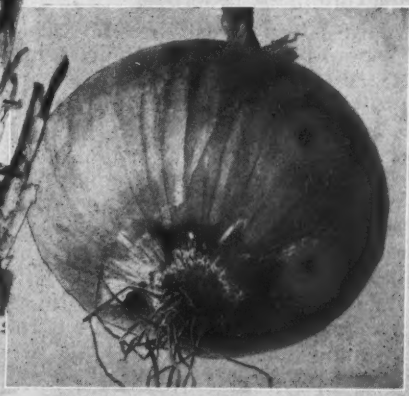
ONION DISEASES AND THEIR CONTROL



ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Pink root is a gradual decay of the roots which does not ordinarily kill the plants but so retards their development that only small bulbs or scallions are produced. Avoid diseased soil, especially for seed beds; rotate crops.

Fusarium bulb rot appears chiefly on old soil as the soil becomes warm after midseason. Rotation with other crops and careful sorting out of decaying bulbs should be practiced.

White rot is a disease relatively new to America and should be reported at once when found. Steam sterilize infested areas and use no bulbs from diseased soil for propagation.

Storage rots—smudge, neck rot, soft rot, Fusarium rot, purple blotch, black mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible. Bulbs showing incipient decay should be carefully sorted out at harvest and when shipping.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

Washington, D. C.

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ONION DISEASES AND THEIR CONTROL

By J. C. WALKER, *Agent, Office of Horticultural Crops and Diseases, Bureau of Plant Industry*

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SCOPE OF THIS BULLETIN

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely, (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference is made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings (fig. 1)—Smut, page 2

2. The leaves, beginning at the tips, turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later (fig. 6)—Mildew, page 7

3. A black moldy growth on leaf tips or seed stalks, often following mildew or purple blotch—Leaf mold, page 10

4. Large purple lesions, sometimes showing zonation, eventually girdling leaves and seed stalks—Purple blotch, page 10

A. Diseases primarily important in the field—Continued.

5. A rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (fig. 7)——Fusarium rot, page 12

6. A condition of the tops quite similar to Fusarium rot but differing in that black round bodies about the size of poppy seeds appear in the diseased bulb (fig. 8)——White rot, page 13

7. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant—Pink root, page 11

8. Orange or golden-yellow pustules appear on leaves or seed stems, especially on those of Egyptian onion——Rust, page 12

9. Pronounced stunting accompanied by various degrees of yellowing——Yellow dwarf, page 14

10. Creeping or twining leafless plants attack leaves of onions, often killing the tops in roughly circular areas in the field (fig. 9)——Dodder, page 14

11. The leaves become a sickly green; swellings form on the roots (fig. 10)——Root knot, page 15

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard black kernels later appear on the surface of affected scales (figs. 11 and 12)——Neck rot, page 19

2. A rot begins at harvest time or later, but differs from neck rot in that it is softer and more watery, usually with a very offensive odor (fig. 13)——Soft rot, page 21

3. A semiwatery rot advancing from the base of the scale upward (fig. 7)——Fusarium rot, page 12

4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (fig. 14)——Black mold, page 22

5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvest time on the outer scales; primarily on white varieties (fig. 15)——Smudge, page 23

6. A semiwatery decay, at first deep yellow, then wine red and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture——Purple blotch, page 10

In addition to these specific diseases there are certain other troubles, due to insects, with which they may be confused:

(1) Thrips injury: Small white chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes associated and confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Onion smut appeared in the United States some 50 years ago, when it was found to be doing damage in the Connecticut River Valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. It does not occur in the southern onion regions. When once introduced it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

CHARACTERISTICS OF SMUT

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves,

the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a powdery black mass of spores in the interior of the blister. Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop. (Fig. 1.) A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are thrown out at harvest time, occasional ones are large enough to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules, most prevalent near the base of the bulbs and often occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

FIGURE 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses

CAUSE OF SMUT

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating, the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage. Experiments show that when the mean soil temperature is 84° F. or above during this period no infection occurs, and the plant having escaped the fungus remains free from the disease. At temperatures somewhat below that mentioned

there is a greater tendency for slightly infected plants to outgrow the disease than at lower temperatures. It is probable that the absence of the disease in the South is due in large measure to these facts, inasmuch as in the southern sections onion seed is sown in August and September, when the soil is extremely warm, while in the North it is sown in the spring, when the soil is cool. After the first leaf (cotyledon) becomes mature the plant becomes immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infested soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who have not been troubled with the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible the returning of infested onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners to some extent have practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the Northern States, where the use of sets or seedlings is impracticable, onion smut is controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to the furrow. (Fig. 2.) It can be made by any tinner. Such an attachment is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary single-row seeder a 2-gallon tank is a sufficient

load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of the seeder, enabling the operator to shut off the flow quickly at the end of the row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 6 or 8 row gang seeder (fig. 3) or with the garden tractor.

Strength and quantity of the solution.—Great care should be used in applying this treatment, since too strong a formaldehyde

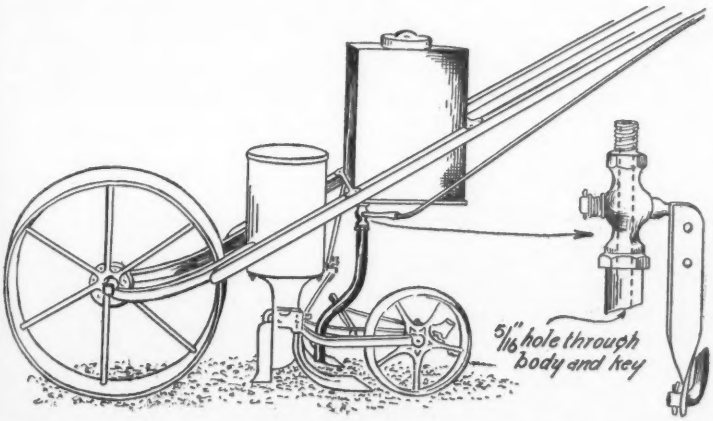

FIGURE 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description)

solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 2 fluid ounces of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 100 gallons per acre, or 1 gallon to about 370 feet of row.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased in

[1] For larger quantities 1 pint to 8 gallons gives the same dilution.

FIGURE 3.—Six-row onion seeder equipped with formaldehyde drip attachment for smut control

FIGURE 4.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand

wholesale quantities, can be obtained at about 15 cents a pound (1930 prices). When a single-row seeder is used, the labor required at the time of sowing is about double, bringing the entire cost of application to about $3 an acre. This is a very insignificant cost compared with the financial return from the operation. (Figs. 4 and 5.)

MILDEW (BLIGHT)

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the leaves become pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse. (Fig. 6.) The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and partially recover. However, on the return of damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the plants, reduces growth, and the bulbs remain small.

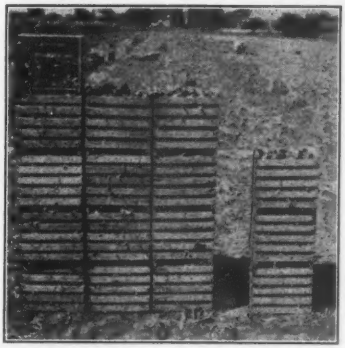

FIGURE 5.—Yield of a smut treated and an untreated row of onions in the field shown in Figure 4. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

CAUSE OF MILDEW

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, among the most important of which are late blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear an abundance of spores. These spores are very light and are readily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt germination of the spores. The resulting fun-

gous growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are borne by air currents to healthy plants where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

FIGURE 6.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station)

CONTROL OF MILDEW

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake the latter and burn them in the fall. Thorough cultivation is essential in order to keep the crop in as vigorous condition as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be considered in a rotation, especially when the general benefits of a 3 or 4 year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included in the rotation.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided.

Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fish oil soap or some other satisfactory spreader should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE[2]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds
Quicklime	4 pounds
Rosin-fish oil soap	3 pounds
Water to make	50 gallons

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solutions and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fish oil soap in a barrel and slowly add water to make 37½ gallons, stirring constantly to avoid the formation of lumps. These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

Provide two 50-gallon barrels each with one head removed and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates,

[2] The section on Bordeaux mixture was prepared by W. B. Clark, formerly of the Bureau of Plant Industry.

mixing in the trough before entering the spray tank. While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fish oil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well distributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

LEAF MOLD

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a secondary fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, following either the mildew or the purple blotch.

PURPLE BLOTCH

Purple blotch is another disease of leaves, seed stalks, and bulbs caused by a hitherto little-known fungus (*Macrosporium porri*). It has been commonly confused with leaf mold because the latter often follows it as a secondary organism. The purple-blotch organism, unlike that of leaf mold, is capable of invading the onion plant quite independently of any forerunner. The disease appears first as small, whitish, sunken lesions with purple centers which rapidly enlarge and eventually girdle the leaf or stalk. Some two or three weeks after its first appearance, darkened zones, which consist of masses of fungous spores, appear on the lesion. Usually the affected leaves or stalks fall over and die within three or four weeks. Thus appreciable damage to both the bulb and the seed crop may be experienced from this disease.

The bulbs are attacked at harvest time. The fungus enters most commonly through the wounded neck, but may invade other wounds on the fleshy scales. The decay is at first semiwatery, but is made noticeable by the color associated with it. The parasite secretes in abundance a pigment which diffuses through the scale tissue somewhat in advance of the fungous threads. Affected tissue is deep yellow at first, turning gradually to a wine red. Eventually it becomes dark brown to black, owing to the profuse development of dark-colored fungous threads in the older decayed tissue. Diseased scales later dry down to a papery texture. Often only one

or two outer scales are affected. In other cases, notably those of white bottom sets, the entire bulb may be destroyed.

No satisfactory control measures for the disease upon the leaves and stalks have been devised. The practices described for the control of onion neck rot (p. 19) are recommended for the bulb rot.

PINK ROOT

Pink root is rapidly becoming one of the more serious onion diseases. Until recently it was confined in its severe form to the Bermuda onion sections of southern Texas. Its first noted appearance in the Delta region of California in 1919 was followed by very heavy crop losses in 1921. In the North it has more recently become of increasing importance in the muck-soil areas of New York, Ohio, and Indiana.

CHARACTERISTICS OF PINK ROOT

The symptoms become manifest in the seed bed or after transplanting. Affected roots shrivel and die and meanwhile take on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and although the affected plants are commonly not killed by the disease, the reduced food supply results in mere scallions or small bulbs being formed. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvest time by the small size of the bulbs, varying with the severity of the attack.

CAUSE OF PINK ROOT

The fungus which causes pink root (*Phoma terrestris*) lives and multiplies in the soil and consequently becomes the more destructive the longer the onions are grown in the same field. It is spread on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

CONTROL OF PINK ROOT

The control of pink root is a very difficult problem when the soil once becomes infested. Diseased soil should be avoided for onion, shallot, or garlic culture. When the onion seed is sown in seed beds, clean soil should be selected. If this is not possible the soil should first be sterilized by the steam-pan method.[3] Plants should never be transplanted from a diseased seed bed to healthy soil. In sections where the disease is known to be serious a long crop rotation should be practiced.

Field experiments by the Texas Agricultural Experiment Station show that factors tending to retard the growth of the plants are very

[3] For details of this method, see Farmers' Bulletin 1629, Steam Sterilization of Soil for Tobacco and Other Crops.

FIGURE 7.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit

favorable to pink root. Some relief from the disease followed the application of fertilizers which would keep the plants in a vigorously growing condition. Indications are that high soil temperature favors the disease, and, where possible, adjustment of the planting date to avoid extremely high soil temperatures is advisable.

FUSARIUM ROT

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is commonly associated with the Fusarium rot affecting the bulb. (Fig. 7.)

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scales upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Indiana, Wisconsin, Iowa, Colorado, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury. It has been shown that certain, if not all, of the causal organisms are most active at comparatively high temperatures. This is probably the chief reason for its appearance after midseason in the North and for its unusual destructiveness in the Walla Walla, Wash., and Uncompahgre, Colo., districts, where very warm weather prevails for some weeks previous to harvest.

Strict attention to sanitary conditions, careful sorting out of diseased bulbs at harvest time, and rotation of crops are the chief measures to be taken for the control of Fusarium rot.

RUST

Two distinct rusts have been noted in North America upon the Egyptian

perennial onion (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri*, has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus-rust fungus (*Puccinia asparagi*), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears on leaves and seed stems before midseason as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or æcia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of Botrytis, very similar to or identical with one of those causing neck rot of onion (p. 19) commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

FIGURE 8.—Onion white rot. Onion plant grown in diseased soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical black sclerotia which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal portion of the plants the tops turn yellow and gradually die

WHITE ROT

White rot, a disease serious on onion, garlic, shallot, and leek, has been reported in northeastern Oregon, near Norfolk, Va., and near Louisville, Ky. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain. This fact is brought to the attention of growers and plant pathologists at this time because large quantities of onions and garlic are being imported from Europe annually and this disease may be introduced again at any time. Any outbreak of the disease upon onion, garlic, or closely related plants answering to the following description should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture.

White rot first appears usually during the cool moist weather in spring or autumn. The first signs are those of yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus (*Sclerotium cepivorum*) which inhabits the soil and invades the roots and the basal portions of the bulb scales. (Fig. 8.) If diseased plants are gently pulled they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungous threads.

Somewhat later this fungous mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with Fusarium rot (p. 12), but in the latter no black sclerotia are ever formed. In the later stages white rot may be mistaken for neck rot (p. 19). In the latter disease black sclerotia are commonly formed. The neck rot sclerotia, however, are several times larger than those of the white rot; moreover, a gray mold is commonly associated with neck rot, while the mold associated with the other disease is distinctly white. Neck rot almost always appears after harvest and starts in most cases at the neck. White rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The parasite is disseminated chiefly by bulbs which have come from diseased soil. Once established, it may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation, and soil once infested should not be used again for onions or closely related plants without being first steam sterilized. In fact, any centers of the disease which are found should be reported at once and the area sterilized, if practicable, to avoid further spread.

YELLOW DWARF

Yellow dwarf was first recognized in a destructive form in the Pleasant Valley district of Iowa in 1928. It had occurred to some extent in that district in 1927 and since then has been found in a few other States. It is most serious on the crop grown from onion sets and upon seed plants. The outstanding symptoms are severe stunting of the plants and in seed plants dwarfing and twisting of the seed stalks. The affected leaves and stems change from their normal green to various degrees of yellowing, extending from a few streaks to almost complete yellowing. It is said to have caused a 25 per cent loss of the crop in the Pleasant Valley district in 1928. It may therefore be considered as a potential hazard to onion growing.

The nature of this disease, its cause, and means of transmission from plant to plant are not wholly understood and are still under investigation. It appears to be one of the virus group of diseases. Evidence so far secured indicates that the causal entity is not carried with onion seed, but that, on the other hand, it is definitely carried in onion sets and mother bulbs. It is therefore most destructive to the crops grown from sets or bulbs. From such a crop it may spread during the growing season to an adjoining crop started from seed. The current-season damage to the latter crop, however, is not serious, but a set crop will be contaminated and dangerous for the next season's propagation.

Pending the results of further investigations the chief precaution to be recommended to those who are producing crops from sets or are producing sets for sale is that fields producing sets, and in fact mother bulbs for seed, should be isolated from other onion fields, particularly from those started from sets of the previous season.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the above-mentioned fungous parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil or are introduced in the spring with the onion seeds. The

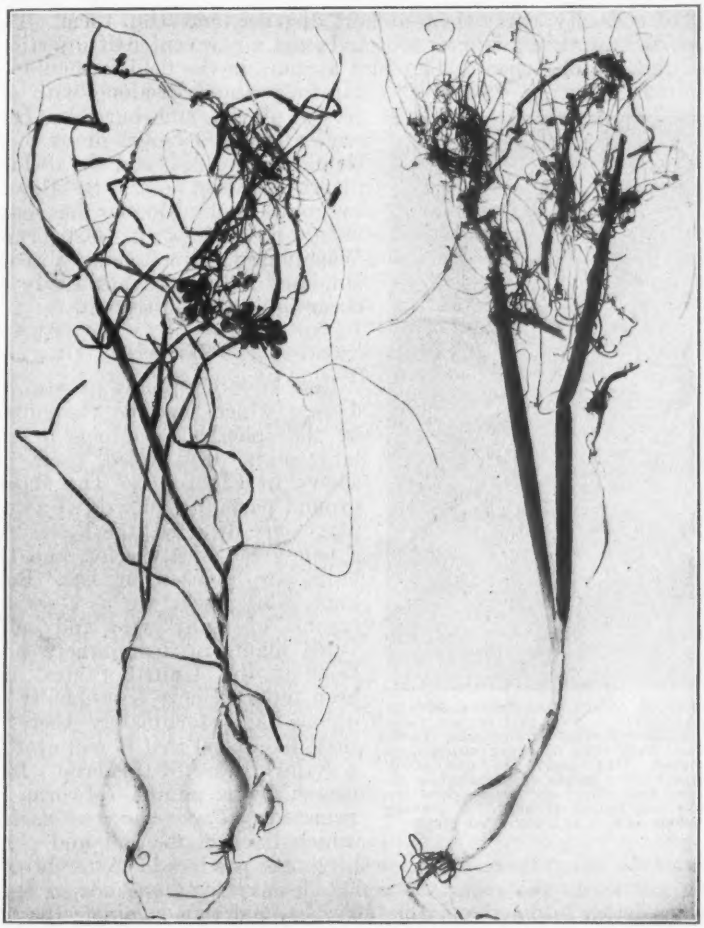

FIGURE 9.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending "suckers" into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants

young dodder plant thus starts off just as the onion seedling does. It has no leaves and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue. (Fig. 9.) After having thus become established as a parasite the dodder gets most of its food from the onion and gradually sends

out its tendrils to attack near-by plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season roughly circular areas of considerable size may occur in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants, out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and it is no doubt likely to occur in any onion section.

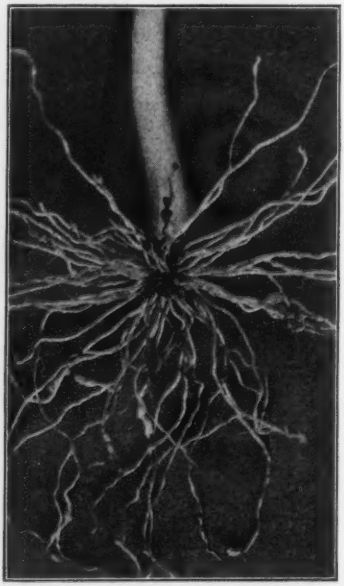

FIGURE 10.—Onion root knot, caused by an eelworm. Note that certain roots contain spherical or irregular swellings, from some of which small, dark masses (the eggs) are protruding. Many active larvae of the eelworm escape from these egg masses into the soil and render it unfit for growing onions as well as many other crops

ROOT KNOT [4]

Root knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in Figure 10. The above-ground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color, and the bulbs are reduced in size. Root knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Caconema radicicola*), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvae), and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where steaming may not be practicable, the number of nematodes can be

[4] The section on root knot was prepared by L. P. Byars, formerly of the Bureau of Plant Industry. For further details on the control of root knot, see Farmers' Bulletin 1345, Root Knot: Its Cause and Control.

reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

To avoid root knot it is advisable never to plant onions on land that is known to be infested with the root knot organism.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth, and on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck rot (p. 19) and soft rot (p. 21), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck rot (p. 19), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for the growing of onions.

HARVESTING[5]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or "stiff necks." These should not be placed in storage, but sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although smut (p. 2) and mildew (p. 7) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (p. 12), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft rot and neck rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. In certain sections where intense sunlight is liable to cause sunburning or scorching of the outer scales it is essential to arrange the plants after pulling so that the bulbs are in every case covered by a layer of tops. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties to damp weather in the field will almost invariably prove disastrous, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible.

[5] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, Onion Culture.

This necessitates walls and roof constructed to afford good insulating materials. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

FIGURE 11.—Onion neck rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black, kernellike masses on the surface

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion regions of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the white and yellow Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK ROT

Neck rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

CHARACTERISTICS OF NECK ROT

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray, feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter. (Figs. 11 and 12.) On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties are infected most readily, while the colored types more often escape it.

CAUSE OF NECK ROT

Neck rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination of air currents. They are thus carried to the healthy bulbs, where they germinate and send fungous threads into the necks, either through the dead tops or through wounds left by the removal of tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungous threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

CONTROL OF NECK ROT

Proper care of the crop during harvest and curing is the chief measure of control for neck rot (p. 19). Avoid exposure to damp weather and provide cool dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation (p. 17) is also very important and worthy of careful consideration in connection with this disease.

ARTIFICIAL CURING FOR THE CONTROL OF NECK ROT

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thor-

oughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

FIGURE 12.—Onion neck rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales

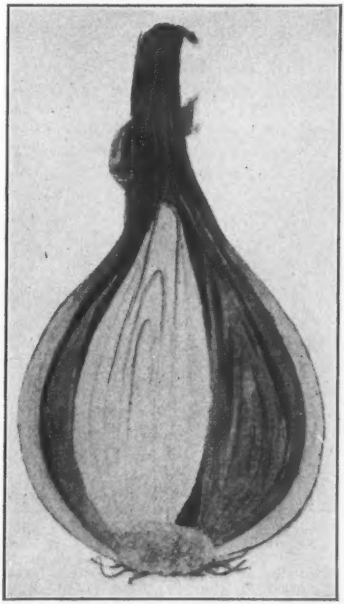

FIGURE 13.—A section of an onion bulb showing bacterial soft rot. This is a watery soft rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact

Experiments are under way with the object of devising the best methods for the application of this principle on a commercial basis. The method is most adaptable to the control of the disease in bottom sets where the necks are more readily cured and the greater value of the crop permits the additional expense involved.

SOFT ROT

Soft rot being of bacterial origin differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes water-soaked in appearance, and later disintegrates into a soft watery

mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. It may also enter through wounds at any point on the bulb. When the rot affects only one or two inner scales, as is often the case (fig. 13), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to careless handling are followed very often by soft rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT ROT

Soft rot is due to a group of bacteria [6] which cause soft rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

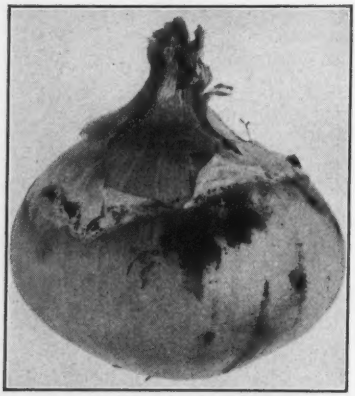

FIGURE 14.—Onion black mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle papery texture

CONTROL OF SOFT ROT

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary measures already recommended (pp. 17 and 18) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

BLACK MOLD

Because of its resemblance in appearance, black mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black mold are borne on the exterior of the scales and can be rubbed off readily. (Fig. 14.) It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool dry environment seems to check it.

Black mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and

[6] *Bacillus carotovorus* is an example of this group.

California, however, it is one of the most important storage and transit diseases.

CAUSE OF BLACK MOLD

Black mold is caused by a fungus (*Aspergillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection, which continues to develop in storage or transit.

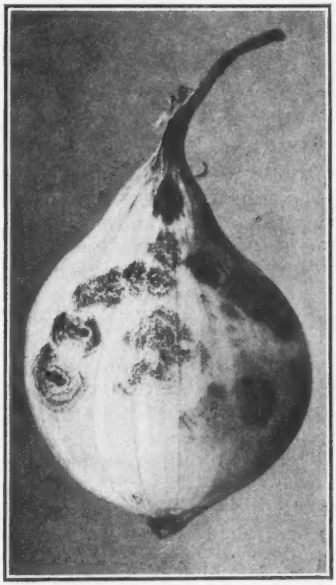

FIGURE 15.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined to the outer scales of white varieties

CONTROL OF BLACK MOLD

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be thoroughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

SMUDGE (ANTHRACNOSE, BLACKSPOT)

Onion smudge is confined largely to white varieties. It appears in the field just before harvest time and continues to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy unsightly appearance to the white bulbs. (Fig. 15.) The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE

Smudge is caused by a fungus (*Colletotrichum circinans*) which lives over winter on onion scales in the soil or on bulbs in the ware-

house, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced. (Fig. 15.) These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

CONTROL OF SMUDGE

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain, if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

SUMMARY OF CONTROL MEASURES

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre or 1 quart to 16 gallons at the rate of 100 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced, it should be done early and thoroughly.

Reduce pink root by avoiding diseased soil, especially for seed beds; rotate onions with other crops.

Fusarium rot requires rotation with other crops or complete abandonment for a time of old onion soils. Sort out all bulbs showing any sign of disease at harvest.

White rot is to be kept from spreading by using no bulbs from diseased soil for propagation and by steam sterilizing infected areas.

Artificial curing is recommended for the control of neck rot under certain circumstances.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry well-ventilated warehouse at 32° to 35° F.

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FARMERS' BULLETIN No. 1060

ONION DISEASES AND THEIR CONTROL

ONION SMUT kills the young seedlings in the spring, is common in old sections, but can be controlled successfully by applying the formaldehyde-drip treatment with the seed.

Mildew is a blight of leaves and seed stems which occurs in a cool humid climate. Good soil and air drainage are essential as means of control.

Pink root is a gradual decay of roots, particularly important in certain peat soils. It does not ordinarily kill the plants but may greatly retard bulb development. When it is severe rotation becomes necessary.

Fusarium rot is a warm-weather disease and most common in the Rocky Mountain irrigated areas. This and other bulb rots, including smudge, neck rot, soft rot, purple blotch, and black mold, are reduced by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible. Bruising should be avoided and bruised and diseased bulbs should be discarded rigidly in the handling operations.

Storage conditions at 32° F. and 65 percent relative humidity are best.

Washington, D. C.

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ONION DISEASES AND THEIR CONTROL

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INTRODUCTION

THE ANNUAL ONION CROP in the United States consists of about 25,000,000 bushels, grown on some 85,000 acres and valued on the farm at $10,000,000 to $15,000,000. Onion culture is intensive, and the growing of the crop entails heavy investment in land, fertilizer, and labor. It is one of the few crops in which repeated croppings, or very short rotations, is commonly practiced. Individual growing areas are thus relatively small and concentrated, but they are not limited geographically, since intensive onion-growing sections are to be found in most States. The 10 States leading in total production are Texas, Michigan, New York, California, Indiana, Massachusetts, New Jersey, Ohio, Colorado, and Minnesota.

Areas producing the table crop may be divided into two groups, namely, (1) those in the northern half of the country, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States from Florida to southern California, in which a winter or spring crop is grown.

In the northern areas most of the crop is grown from seed sown directly in the field in early spring at the rate of 3 to 5 pounds per acre. No thinning of stand is made after sowing. Both upland and muck soils are used, but in recent years the acreage has increased rapidly on muck until now it comprises the greater portion. The common varieties are Yellow Globe, White Globe, Red Globe, and Yellow Danvers in the East and Midwest, with additional varieties

such as Australian Brown in California. In the Rocky Mountain areas on irrigated alluvial soils the Sweet Spanish varieties are grown extensively. In the midwestern and eastern areas relatively small acreages of earlier onions are grown from sets. These are flat varieties such as Yellow Strassburg, Ebenezer, Red Wethersfield, White Portugal, and the oblong bulb variety Yellow Bottleneck. Most of the northern crop is carried in storage for varying periods and is placed on the consuming market throughout the country up to March and April.

The southern crop is grown in part from northern-grown sets of the Yellow Strassburg, Ebenezer, Red Wethersfield, and White Portugal varieties. The bulk of the crop, however, is of the very flat, mild-flavored Bermuda type, chiefly Yellow Bermuda, Crystal Wax, and to a limited extent Creole. The seed is sown in late summer and early autumn in seedbeds, whence plants are set during midwinter months. Much of the acreage is under irrigation. The crop matures in April and May. These southern crops thus supply the consuming markets throughout the country during April, May, June, and July and are followed by the earliest northern onions grown from sets. The Bermuda type is not adapted to long storage and the marketing season of this crop is thus much shorter than that of the northern crop.

Onion sets are chiefly of the Red Wethersfield, Yellow Strassburg, Ebenezer, and White Portugal varieties. They are grown in several Northern States, always on upland or alluvial soil. The majority is produced in the Chicago area extending from northwestern Indiana, through northeastern Illinois and southeastern Wisconsin. The seed is sown in early spring, as in table onions, but at the rate of 75 to 80 pounds of seed per acre. Some of the crop is shipped south immediately after harvest for fall planting; most of it is stored and shipped during the winter and throughout the spring. Onion sets are widely distributed and used generally for spring bunching onions in the home garden and on the commercial truck farm.

Onion seed was formerly grown chiefly in Connecticut, New York, and Ohio. Most of it is now produced in California, where summer-matured bulbs are planted in the autumn and seed plants grow during the winter to flower and mature during the dry summer. Seed of the Bermuda type is grown almost exclusively in the Canary Islands.

It may be seen from this brief survey of the onion industry that the crop is grown under a variety of climatic conditions and on a wide range of soils. As environmental factors have a direct bearing upon disease, the preeminent diseases vary with geography. In the following discussion of diseases, reference will be made repeatedly to specific growing regions and cultural practices.

DESCRIPTIVE KEY TO ONION DISEASES

The following key of the outstanding symptoms of onion diseases will aid in their recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings (fig. 1)---------- Smut, page 3

2. Rapid death of young seedlings in circular patches in the field ..... Damping-off, page 7
3. The leaves, beginning at the tips, turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later (fig. 6) ..... Mildew, page 7
4. A black moldy growth on leaf tips or seedstalks, often following mildew or purple blotch ..... Leafmold, page 9
5. Large purple lesions, sometimes showing zonation, eventually girdling leaves and seedstalks ..... Purple blotch, page 9
6. A rapid dying-back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (fig. 7) ..... Fusarium rot, page 11
7. A condition of the tops quite similar to fusarium rot but differing in that round black bodies about the size of poppy seeds appear in the diseased bulb (fig. 8) ..... White rot, page 12
8. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant ..... Pink root, page 10
9. Orange or golden-yellow pustules appear on leaves or seed stems, especially on those of the Egyptian onion ..... Rust, page 11
10. Pronounced stunting accompanied by various degrees of yellowing ..... Yellow dwarf, page 13
11. Creeping or twining leafless plants attack leaves of onions, often killing the tops in roughly circular areas in the field (fig. 9). Dodder, page 15
12. The leaves become a sickly green; swellings form on the roots (fig. 10) ..... Root knot, page 15

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard black kernels later appear on the surface of affected scales (figs. 11 and 12) ..... Neck rot, page 18
2. A rot begins at harvesttime or later, but differs from neck rot in that it is softer and more watery, usually with a very offensive odor (fig. 13) ..... Soft rot, page 20
3. A semiwatery rot advancing from the base of the scale upward (fig. 7) ..... Fusarium rot, page 11
4. Black powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (fig. 14) ..... Black mold, page 21
5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvesttime on the outer scales, primarily on white varieties (fig. 15) ..... Smudge, page 22
6. A semiwatery decay, at first deep yellow, then wine red, and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture ..... Purple blotch, page 9
7. Dry decay of garlic, with brown kernellike bodies in and on decay tissue ..... Aspergillus rot, page 23

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Smut is a disease in which the causal organism remains viable in the soil for many years. Smut-infested soil is therefore likely to remain so indefinitely and is found usually in areas where onions have been grown intensively for a long time. This disease is to be found in many onion regions in the Northern States from coast to coast. It is not a factor in the winter-growing southern regions, where its almost complete absence is due largely to climatic conditions.

CHARACTERISTICS

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves,

the latter usually being slightly thickened and often curved downward abnormally. These blisters often break open, exposing black powdery masses which are made up of the spores of the causal fungus. A majority of the infected seedlings die within 3 to 5 weeks after germination. Such thinning of the stand is thus an early and important feature of smut injury, although a small percentage of infected seedlings outgrow the disease. Some diseased plants survive until midseason or harvest, new leaves and scales becoming infected as they develop. Figure 1 shows a half-grown infected plant which has survived the seedling stage. Such plants usually produce bulbs so small and imperfect that they are thrown out at harvest. Occasionally, infected bulbs are large enough and so slightly affected as to escape notice and reach warehouse and market. Such specimens are characterized by slightly raised brown to black pustules most prevalent near the base of the outer fleshy scale and occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

FIGURE 1.—Onion smut. A half-grown plant showing brown to black unbroken blisters in the scales and leaves. When the blisters or pustules break open the black powdery masses of spores of the smut fungus are exposed.

THE CAUSAL ORGANISM

The fungus parasite (*Urocystis cepulae*), associated with onion smut, infects only the onion and certain closely related species of plants such as leek, Welsh onion, and wild forms. Most varieties of the Welsh onion are resistant to the disease. The black powdery masses which are exposed upon the splitting of the blisters or pustules in the onion leaf consist of myriads of spores or seed bodies which propagate the fungus. These spores are highly resistant to environmental changes, and as they become incorporated in the soil they remain viable for many years. This is the reason that continuous cropping is favorable to the accumulation of the fungus and that soil once infested remains so indefinitely.

The spores germinate by sending out fungus threads which permeate the soil and often break up into innumerable secondary spores. These stages of the fungus survive only for short periods and are sensitive to cold and drought. The threads penetrate young onion

seedlings and, taking nourishment from the plant, form the characteristic blisters within the tissue, finally climaxing in the development of more dark spores.

Important to the understanding of onion smut and its control is the fact that the fungus can invade the onion plant only in the early seedling stage. If the outer seedling leaf (cotyledon) escapes infection until it is mature (about 3 weeks from germination), no further invasion occurs even in very heavily infested soil. This is the reason why smut is not a disease factor when the crop is started from sets or slips (seedling transplants), even though they are set in smutty land. When the mean soil temperature is 84° F. or above during the period of the seedlings' susceptibility, no infection occurs, because the fungus is inactive at this high temperature. At slightly lower temperatures the seedlings tend to outgrow the disease more effectively than in cool soil. These temperature relations explain the

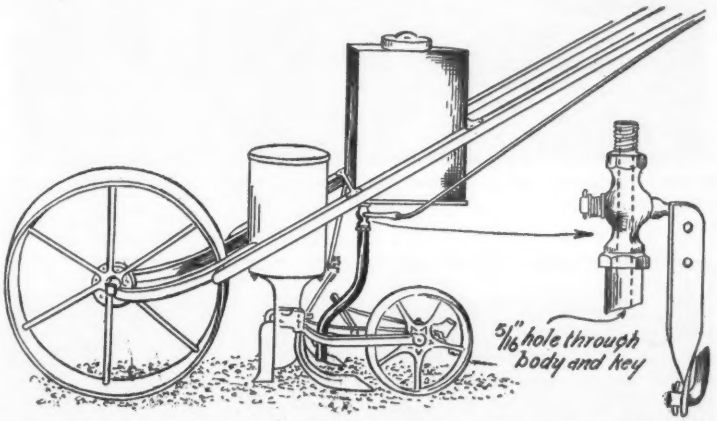

FIGURE 2.—Single-row onion seeder equipped with a formaldehyde-drip attachment for onion-smut control. Note that the disinfectant is introduced into the furrow just after the seed is dropped and before the furrow is covered. The cut-off valve is regulated from the handle of the seeder.

absence of the disease on the southern onion crops where the seed is sown in late summer. The seedlings are thus started off in very warm soil, which is unfavorable to smut. In the main crop of the Northern States the seedlings come up in cool soil, and the smut fungus, if present, is not inhibited.

The spores of smut are spread locally by farm implements, by the feet of men and animals, by surface drainage water, and by airborne soil. The transfer from locality to locality is rarely made through the medium of seed, but commonly by means of onion sets grown on smutty soil.

CONTROL

As stated above, the crop started with sets or slips is not affected. In the main crop of the North, started from seed in the field, the disease is controlled by the formaldehyde-drip method. This consists of the application of a stream of dilute formaldehyde in the

furrow with the seed. The vapor of the formaldehyde permeates the soil in the area between the seed and the soil surface sufficiently to disinfect it temporarily insofar as smut is concerned. The young

FIGURE 3.—A six-row seeder equipped with the formaldehyde drip attachment for smut control.

FIGURE 4.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has resulted in the death of a large percentage of the plants in the two untreated rows in the center; the remainder of the field has practically a full stand.

seedling is thus protected during its susceptible period. The effectiveness of the treatment is sometimes reduced if heavy rain follows immediately after sowing; however, a lapse of 24 hours without rain usually insures successful control.

The attachments of formaldehyde tanks to single-row seeders and to horse-drawn gang seeders are shown in figures 2 and 3. The effect of the treatment on stand and yield is shown in figures 4 and 5.

There is some latitude in the strength of the formaldehyde solution and the rate of application. When 14-inch rows are planted, the best results have been secured with a solution made from 1 pint of concentrated formaldehyde to 16 gallons of water, applied at the rate of 200 gallons per acre. Almost as effective results were secured with a solution of 1 pint to 8 gallons of water, applied at the rate of 100 gallons per acre. The latter formula is now the more commonly used. The cost of materials and extra labor is about $3 per acre.

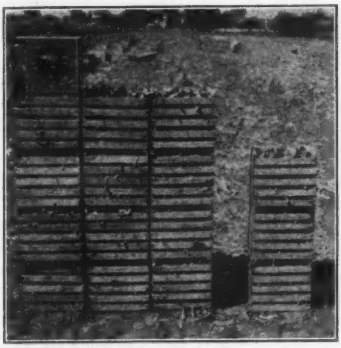

FIGURE 5.—Yield of a treated and of an untreated row of onions in the field shown in figure 4. The treated rows averaged 545 bushels; the untreated ones 200 bushels per acre.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly, since a stream of liquid in each individual row is essential.

DAMPING-OFF

Damping-off is a disease common to seedlings of many plants. One or more of several soil fungi may be involved. When seedlings are growing rapidly they are subject to attack by these fungi, whereas they are resistant at other times. The plants are attacked at or slightly below the soil line, and the tissue shrinks rapidly while the still turgid above-ground parts topple over. Damping-off in onions does not ordinarily take the form of thinning out plants here and there, but more often kills practically all plants in roughly circular areas variable in size. There is no specific remedy for this disease. The best cultural practices, such as frequent cultivation, good drainage, and good fertility, all discourage damping-off by providing the most favorable growing conditions for the onion plant.

MILDEW

Onion mildew has been reported from most States where onions are grown. Its destructiveness varies widely with locality and season. Relatively cool, moist weather is most favorable for its development. Losses are most severe on the bulb crop in New York, Oregon, and Michigan. In California losses in the seed crop during the winter and spring are sometimes heavy, since the foggy weather is especially favorable to the mildew which attacks the seedstalks, causing them to fall over before the seed is mature.

CHARACTERISTICS

The first symptoms are found most realiy by examining leaves closely in the early morning while the dew is still present. The violet furry growth on the surface of the leaf or seed stem is characteristic. The affected leaves gradually become pale green and later yellowish, and the diseased portions collapse. The furry growth becomes more widespread if the humidity remains high, but the advance and spread is very dependent on favorable weather. The disease commonly starts in spots in the field and spreads to surrounding areas. If the weather remains dry following an outbreak, plants send out new leaves and partially recover, but on the return of humid conditions the fungus revives and new plant growth becomes blighted. Repeated killing of leaves in this manner reduces growth, and the bulbs remain small, while the necks are unduly succulent and subject to attack by storage-decay organisms. Lesions on onion-seed stems are circular or elongate, often affecting only one side of the stalk, but weakening the latter and causing it to break over from the weight of the seed umbel. This causes shriveling of the seeds. The fungus may infect the flower parts as well, and there is circumstantial evidence that it is carried with the seed (fig. 6).

FIGURE 6.—Onion mildew. Note the fungus growth on the dying older leaves; the two youngest leaves are not affected as yet. The furry masses (mildew) on the diseased leaves consist of fruiting branches of the causal fungus and many thin-walled light microscopic spores, which are readily disseminated by the wind.

THE CAUSAL ORGANISM

The causal organism (*Peronospora destructor* (Berk.) Caspary) is closely related to those associated with potato late blight, grape mildew, and cucumber downy mildew. The onion fungus is confined largely to onion, Welsh onion, and chives. Garlic and leek have been reported as hosts, but it is not certain that they are subject to infection by the same strain as onion. The furry masses on the affected parts of the plant are made up of branches of the fungus which extend above the surface and bear numerous microscopic spores. These spores are thin-walled and light; they are easily detached and transported by air currents, and this is the chief means whereby the fungus is disseminated locally. They are short-lived, however, and very sensitive to drying. If moist

weather favorable to infection does not prevail, most of them die without causing infection.

When damp weather prevails, the spores germinate promptly, and if this occurs on the leaf surface the germ tube growing into a thread enters through a breathing pore (stomate) and into the internal tissue. As the fungus absorbs food from the onion the cells of the latter gradually succumb; as a result the leaves turn yellow, shrivel, and die. The fungus sends fruiting branches to the surface, where it produces more spores.

Another type of spore, the resting spore or oospore, is formed in the dying plant tissues. This has a thick wall and a concentrated food supply and is suited to withstand unfavorable environment. The internal threads or mycelium also survive long periods, especially when they get into the bulb before it matures. Oospores and mycelium may be carried with the seed. Thus the fungus lives over unfavorable periods as oospores or as mycelium in bulbs and sets, in seed, and in the soil, and may be transported long distances with bulbs and seed.

CONTROL

While many downy mildews such as grape mildew and potato late blight are successfully controlled by spraying with bordeaux mixture, this has never proved to be the case with onion mildew. One drawback is the great difficulty in securing thorough coverage of the very waxy foliage. A second handicap is the continual emergence of new leaves from the neck, necessitating very frequent applications for complete protection.

In regions where mildew occurs frequently cultural practices are about all that can be applied to reduce losses, and these are not wholly effective. Burning refuse to reduce the carry-over of the resting spores and mycelium is advised, and continuous cropping to onions should be avoided. Adequate seed-treatment methods have not been devised as yet. Onions should not be planted in fields with poor air drainage. Good soil drainage, frequent cultivation of the crop, and adequate fertility all help by providing favorable conditions for plant growth. Cultivating the crop while dew or rain is still on the foliage is not advisable.

LEAFMOLD

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a secondary fungus (*Thyrospora parasitica*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seedstalks following either the mildew or the purple blotch.

PURPLE BLOTCH

Purple blotch is a disease of leaves, seedstalks, and bulbs. It has been commonly confused with leafmold because this organism commonly follows purple blotch as a secondary invader. However, unlike the leafmold organism, the purple blotch organism is capable of invading the onion plant quite independently of any forerunner. The

disease is of some importance on the seed crop and sometimes causes appreciable losses as a bulb rot. The causal organism appears to be rather widespread in occurrence.

CHARACTERISTICS

The disease appears first as small, whitish, sunken lesions with purple centers that rapidly enlarge and eventually girdle the leaf or stalk. About 2 or 3 weeks after its first appearance, darkened zones, consisting of superficial masses of fungus spores, appear on the lesion. Usually the affected leaves or stalks fall over and die within 3 or 4 weeks after lesions appear, if the environment is favorable for disease development. Purple blotch requires less humid weather than mildew; thus it is much less limited in geographic distribution.

The bulbs are attacked at harvesttime. The fungus invades most commonly through the neck, but may invade wounds on the fleshy scales. The decay is at first semiwatery and is made especially conspicuous by the color associated with it. The parasite secretes in abundance a pigment which diffuses through the scale tissue somewhat in advance of the fungus threads. Affected tissue is deep yellow at first, turning gradually to a wine red. With the profuse development of dark-colored fungus threads, the older decayed tissue eventually becomes dark brown to black. As the tissue becomes desiccated the diseased scales eventually dry down to a papery texture. Often only one or two outer scales are affected; in other instances, notably with white bottom sets, the entire bulb may be destroyed.

THE CAUSAL ORGANISM

The causal fungus (*Macrosporium porri* Ell.) is closely related to that associated with early blight of potato and tomato. It is confined, however, to onion and possibly such closely related plants as leek and chives. The spores, which are produced on short fruiting branches on the surface of the decayed leaves, stems, and scales, are many-celled, dark colored, and capable of withstanding unfavorable environment; thus they carry the fungus through northern winters or hot southern summers. They germinate to produce fungus threads (mycelium) that invade the stomates of leaves and the stems and wounds on the bulbs.

CONTROL

No satisfactory control measures for the disease on leaves and stems have been devised. The practices described for the control of onion neck rot (p. 18) are recommended for the bulb rot.

PINK ROOT

Pink root is serious in the delta region of California, in the Rio Grande Valley of Texas, and in muck-soil districts of New York, Ohio, and Indiana.

The symptoms become manifest in the seedbed or after transplanting. Affected roots shrivel and die, meanwhile taking on a distinctly

pink color. Abnormal yellowing of the roots is commonly associated with pink root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and, although the affected plants are commonly not killed by the disease, the reduced food supply results in the formation of mere scallions or small bulbs. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvesttime in the small size of the bulbs, varying with the severity of the attack.

The fungus which causes pink root (*Phoma terrestris* Hansen) lives and multiplies in the soil; consequently, it becomes more destructive the longer the onions are grown in the same field. It is disseminated on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

When pink root becomes serious on a given area the best procedure is to practice long rotation. Slips or sets from pink root infested soil should be avoided. Good cultural practices and high fertility are helpful. Efforts are being made to develop satisfactorily resistant varieties.

FUSARIUM ROT

Fusarium rot is a widespread disease, but it seldom causes severe losses. In the Rocky Mountain irrigated valleys it sometimes reaches economic proportions.

Rapid dying back of the leaves from the tips when plants are approaching maturity is the first evidence of the trouble. Most of the roots are eventually rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them a semiwatery decay is found, advancing from the base of the scales upward. The rot progresses somewhat slowly, and many recent infections are unnoticed at harvesttime. Thus the disease becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

The causal fungi (*Fusarium* spp.) live in the soil. Infection of the plants is sometimes correlated with maggot injury. Invasion occurs through wounds or in the vicinity of old root scars at the base of the bulb. The disease is favored by high soil temperatures, which is probably the chief reason for its appearance in the Northern States after midseason and for its more common destructiveness in the western valleys, where high temperatures are not unusual.

Careful sorting at harvest is recommended. Rotation is necessary when this disease becomes troublesome (fig. 7).

RUST

Two distinct rusts have been noted in North America upon the Egyptian perennial onion (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri* (Sow.) Wint., has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus rust fungus (*Puccinia asparagigi*

FIGURE 7.—Fusarium rot. Decay starts at the base of the scales and causes the leaves to die back from the tips; the bulb continues to rot in storage and in transit.

DC.), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears before midseason on leaves and seed stems as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or aecia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of *Botrytis* very similar to or identical with one of those causing neck rot of onion (p. 18), commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE ROT

White rot, a disease serious on onion, garlic, shallot, and leek, has been reported in northeastern Oregon, near Norfolk, Va., and near Louisville, Ky. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain. Since onion and garlic are imported from Europe annually this disease may be introduced again at any time. Any outbreak of the disease upon onion, garlic, or closely related plants answering to the following description should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture.

White rot first appears usually during the cool, moist weather in the spring and autumn. The first signs are yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus *Sclerotium cepivorum* Berk., which inhabits the soil and invades the roots and the basal portions of the bulb scales (fig. 8). If diseased plants are gently pulled, they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a

white fluffy mass of fungus threads. Somewhat later this fungus mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with fusarium rot (p. 11), but in the latter no black sclerotia are ever formed. In the later stages white rot may be mistaken for neck rot (p. 18). In the latter disease black sclerotia are commonly formed. The neck rot sclerotia, however, are several times larger than those of the white rot; moreover, a gray mold is commonly associated with neck rot, while the mold associated with the other disease is distinctly white. Neck rot almost always appears after harvest and starts in most cases at the neck. White rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The parasite is disseminated chiefly by bulbs that have come from diseased soil. Once established, the parasite may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation, and soil once infested should not be used again for onions or closely related plants without being first steam-sterilized. In fact, any centers of the disease that are found should be reported at once and the area sterilized, if practicable, to avoid further spread.

FIGURE 8.—Onion white rot. Onion plant grown in diseased soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical black sclerotia which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal portion of the plants the tops turn yellow and gradually die.

YELLOW DWARF

Yellow dwarf was first recognized in a destructive form in the Pleasant Valley district of Iowa in 1928. It had occurred to some extent in that district in 1927 and since then has been found in a few other States. It is most serious on the crop grown from onion sets and upon seed plants. The outstanding symptoms are severe stunting of the plants and, in seed plants dwarfing and twisting of the seedstalks. The affected leaves and stems change from their normal green to various degrees of yellowing, extending from a few streaks to almost complete yellowing. It is said to have caused a 25-percent loss of the crop in the Pleasant Valley district in 1928. Since that time effective means of control have been perfected.

Yellow dwarf is a virus disease, which means that it is transmissible and infectious, but the contagious entity or virus is ultramicroscopic and not identifiable in the form of a bacterium or fungus. The virus lives over in bulbs of infected plants. When such bulbs or sets are

planted, the next year the plants are diseased and contain the virus throughout the leaves. The virus is then carried to surrounding healthy plants by plant lice, and thus the contagion may spread rapidly during the growing season. Yellow dwarf is not serious where the crop is grown from seed only, since the virus is not carried in the seed. Where bulbs are carried over as sets or for the propagation of seed in proximity to onions from seed there is opportunity for continual carry-over and propagation. It is under such conditions that yellow dwarf has become very serious.

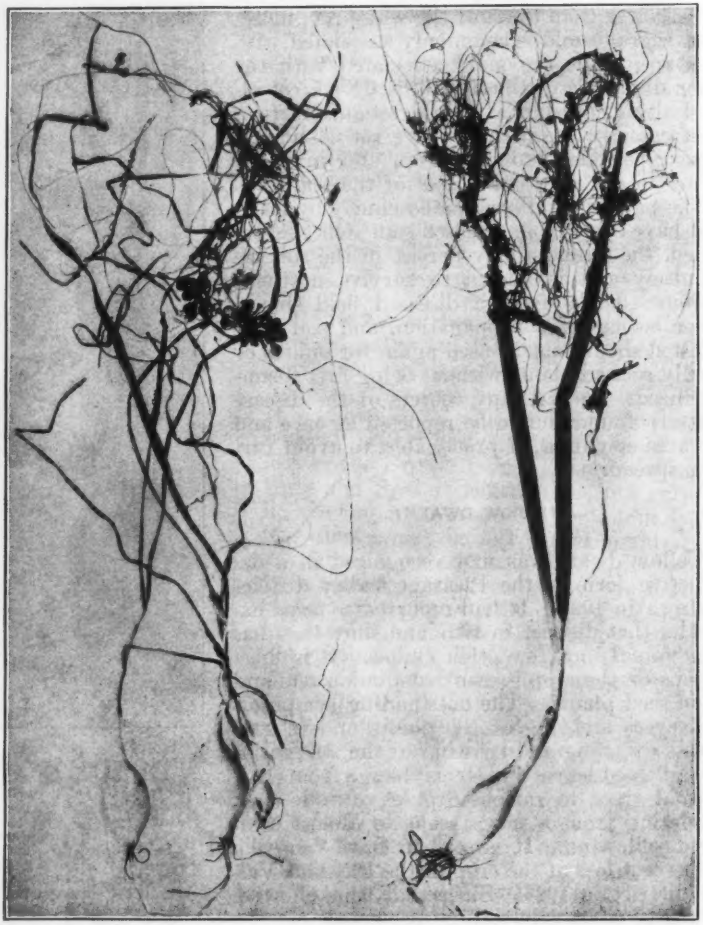

FIGURE 9.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending suckers into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants.

Onion sets should not be grown in proximity to a bulb crop grown from sets of the previous year or to a seed crop. In this way carry-over of the virus is limited. Onion sets can be indexed in the greenhouse during the winter months for the presence of the yellow dwarf virus.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the previously mentioned fungus parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil and are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves, and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue (fig. 9). After having thus become established as a parasite, the dodder gets most of its food from the onion and gradually sends out its tendrils to attack nearby plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season roughly circular areas of considerable size may occur in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and, doubtless, it is likely to occur in any onion section.

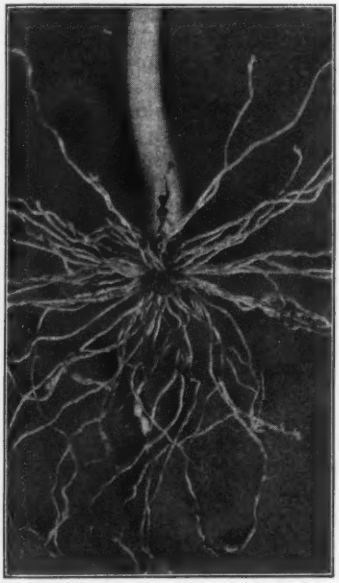

FIGURE 10.—Onion root knot, caused by an eelworm. Note that certain roots contain spherical or irregular swellings, from some of which small dark masses (the eggs) are protruding. Many active larvae of the eelworm escape from these egg masses into the soil and render it unfit for growing onions, as well as many other crops.

ROOT KNOT

Root knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in figure 10. The aboveground parts of badly diseased plants are dwarfed, the leaves are a sickly pale-green color, and the bulbs are reduced in size. Root knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of

the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm or nematode (*Heterodera marioni* (Cornu) Goodey), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvae), thus completing the life cycle.

When soil becomes infested with root knot eelworms it should be planted for 2 or more years with crops not subject to this nematode before a susceptible crop is grown. A list of resistant crops that may be used in rotation is given in Farmers' Bulletin 1345.

STEM NEMATODE

A strain of the bulb nematode (*Ditylenchus dipsaci* (Kühn) Filipj) which occurs on hyacinth and tulip is specialized on onion. It has been found only rarely in this country. An outbreak in New York State was eradicated in 1932. Any occurrence of this malady should be reported at once to the United States Department of Agriculture or to the State experiment station.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth and, on going into its dormant state, becomes more susceptible to the attack of storage rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant, the bulbs must be allowed to sweat or cure, preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture that is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck rot (p. 18) and soft rot (p. 20), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck rot (p. 18), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest or the field should be plowed promptly. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for growing onions.

HARVESTING

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly, it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or stiff necks. These should not be placed in storage, but should be sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms that cause decay. The milling of sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvesttime to throw out all bulbs that show any signs of disease or insect injury. Although smut (p. 3) and mildew (p. 7) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage rot organisms. Fusarium rot (p. 11), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft rot and neck rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. In certain sections where intense sunlight is likely to cause sunburning or scorching of the outer scales it is essential to arrange the plants after pulling so that the bulbs are in every case covered by a layer of tops. It is preferable, however, to

place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties to damp weather in the field will almost invariably prove disastrous; they should be placed in a curing shed where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulation. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results. The best relative humidity for storage is about 65 percent.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck rot and smudge, and handling them successfully requires much more care during harvest and curing. In the onion-set growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion districts of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest because of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite, because it resists the attacks of fungi and bacteria in storage and in transit much more effectively than the white and yellow Bermuda varieties.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK ROT

Neck rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 percent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties (fig. 11).

CHARACTERISTICS

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound. There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray, feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 11 and 12). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties are infected most readily, while the colored types more often escape it.

FIGURE 11.—Onion neck rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black, kernellike masses on the surface.

FIGURE 12.—Onion neck rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales.

THE CAUSAL ORGANISM

Neck rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds that attack lettuce, cabbage, and numerous other vegetables. These fungi are

not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination of air currents. They are thus carried to the healthy bulbs, where they germinate and send fungus threads into the necks, either through the dead tops or through wounds left by the removal of tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungus threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

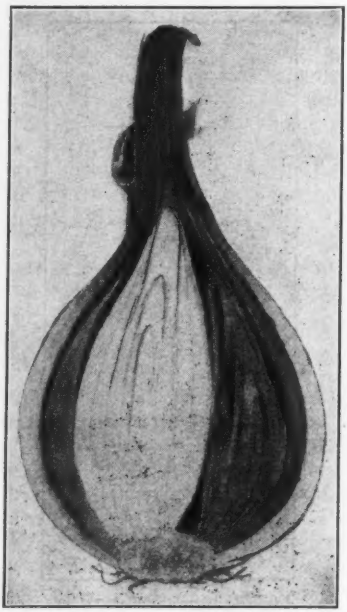

FIGURE 13.—Section through a bulb affected with soft rot. Beginning at the neck, the tissue is water-soaked and later becomes soft and slimy, giving rise to an offensive sulphurous odor. The rot advances down those scales which happen to become infected at the neck but does not go readily from scale to scale.

CONTROL

Proper care of the crop during harvest and curing is the chief measure of control for neck rot (p. 18). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, as they are very susceptible to the disease. Proper sanitation (p. 17) is also very important and worthy of careful consideration in connection with this disease.

Artificial curing of white onion sets is advisable when curing weather is unfavorable and neck rot has started to appear. This requires special equipment and is not ordinarily economical for the average grower, but may be advantageous to the dealer who contracts for sets for storage and shipment. The sets are placed in a kiln in the shallow slatted crates in which they are ordinarily cured. Warm air at 100° to 120° F. is forced through them by a blower for several hours, until the neck tissue is thoroughly dry. If the neck rot fungi have not advanced very far, the desiccation of the scale tissue checks their advance completely.

SOFT ROT

Soft rot usually begins at the neck of the bulb, advancing down one or more scales (fig. 13). It sometimes starts in bulbs in the field slightly before harvest. The tissue is at first water-soaked; later it disintegrates into a soft slimy mass. An offensive sulphurous odor is usually given off, a characteristic that serves to distinguish it from

other bulb decays. The decay does not pass readily from scale to scale. It may start at bruises or wounds on the scales and commonly follows in tissue injured by freezing. When the rot affects only one or two inner scales, as is often the case, the only external sign of the disease is the lack of firmness of the bulb and often the appearance of a watery exudate through the neck when pressure is applied to the upper part of the surface of the bulb.

Soft rot differs from the disease discussed previously in that the causal organism (*Bacillus carotovorus* L. R. Jones) is one of the bacteria rather than a fungus. It is the same one which causes soft rot of other vegetables, such as cabbage, carrot, and celery. The organism is widespread in its occurrence but invades usually dormant storage parts of the plant and enters only through wounds and in moist environment. Maggot larvae may carry the bacteria and through their feeding on bulbs provide the necessary wounds for infection. The bacteria may persist in the intestinal tract of the larvae and the adult fly and thus be carried from place to place. The eggs may be contaminated when laid by the fly, and thus the soft rot bacteria become identified closely with the life history of the maggot, depending upon the latter for its perpetuation and dissemination.

The precautionary measures already recommended on pages 17 and 18 regarding harvesting, curing, and storing should be followed carefully.

FIGURE 14.—Black mold. Irregular sooty masses occur on the outside of the scales or between them. The outer scales shrivel about the neck of the bulb and assume a brittle papery texture. Compare with onion smut.

BLACK MOLD

Black mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

Because of its resemblance in appearance, black mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black mold are borne on the exterior of the scales and can be rubbed off readily (fig. 14). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it. While most

conspicuous on white varieties, it occurs commonly on all colored-bulb varieties.

The causal organism (*Aspergillus niger* Tiegh.) is a very common saprophyte, living on almost any dead or dying vegetable matter. Where it is most serious on onions it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but it is not noticeable until the onions are pulled. Rainy weather at this critical period will result in widespread infection, which continues to develop in storage and transit.

To hold black mold in abeyance general sanitary measures and protection from moisture after harvest are essential. Bulbs should be thoroughly dry before being shipped, since moisture in the pack favors rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage, in order to hold the disease in check.

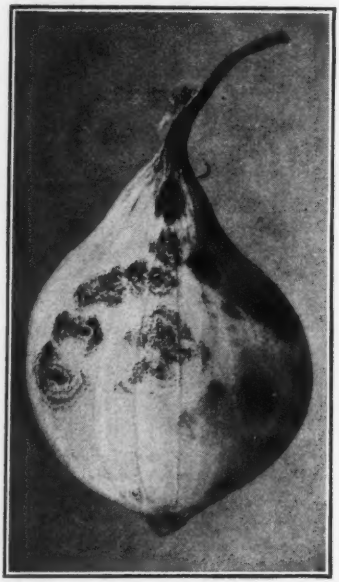

FIGURE 15.—Onion smudge. Black smudgy spots made up of small black dots occur on the outer scales of white varieties. There is a slow invasion of the fleshy scales.

SMUDGE

Onion smudge is confined largely to white varieties. It appears in the field just before harvesttime and continues to develop during the storage period. It is characterized by small, dark-green to black dots, which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 15). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, the chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

The causal fungus (*Colletotrichum circinans* (Berk.) Vogl.) lives over between seasons on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown in the same fields year after year. It is widely distributed through the trade on white onion sets and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots, on which myriads of minute spores are produced (fig. 15). These

spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

Susceptibility to this disease and to neck rot has greatly reduced the acreage of white varieties in northern areas. Special care at harvesttime is necessary in handling them. The crop must be harvested promptly, exposure to rain avoided if possible, and rapid and thorough curing insured. Artificial curing is helpful, but it is seldom necessary except with onion sets in which neck rot also threatens to develop.

ASPERGILLUS ROT

Aspergillus rot is a decay of garlic bulbs which has been found twice on imported stock. The scales are reduced to a rather dry powdery condition, and through the mass are brown kernels (sclerotia) two or three times the size of the head of a pin. The causal fungus (*Aspergillus alliaceus* Thom and Church) commonly fruits on the surface as a lemon-yellow mold, similar except in color to black mold. The fungus, though never found on the onion as yet, readily decays onion bulbs when it once gains entrance. The sclerotia are somewhat larger and browner than those of the white-rot organism and smaller than those of the neck-rot fungi. Attention is called to its occurrence, since it is likely to be found on the onion at some future time. The parasite works only at somewhat high summer temperatures and thus will not be serious as a rot in cold storage.

NONPARASITIC BLEMISHES AND MALADIES

FREEZING INJURY

Occasionally onions are subjected to freezing temperatures. Growing plants may be killed if the temperature is low enough and lasts long enough. The Bermuda and Sweet Spanish varieties are much more susceptible than the Globe varieties. The first-named types are also more likely to show a larger percentage of doubles and multipliers among the plants that survive freezing in the field.

Bulbs exposed to freezing temperatures in the field, in storage, or in transit will show freezing injury. The average freezing temperature for onions of the globe type is about 30° F. It is possible to cool them below the freezing point without injuring them. If they are handled or moved in the undercooled condition, ice formation in the tissues occurs and damage sets in. Undercooled bulbs suffer less damage if they are thawed out at 50° or above than if thawed slowly at 32°.

Freezing injury can be determined by cutting the bulb longitudinally or transversely. The affected tissue is water-soaked, discolored, and more or less transparent, having indefinitely scattered opaque areas. Freezing injury is easily confused with physiological breakdown discussed on page 24. It is not uncommon to find some scales injured and others not, because of the fact that the freezing point of

the tissues varies. Thus the outer scale may be injured, the next one sound, the third injured, the next sound, and so on. Soft rot commonly follows the freezing injury. If it is confined to the outer scales, the bulbs can usually be salvaged by being spread in thin layers and allowed to dry out.

PHYSIOLOGICAL BREAK-DOWN

Physiological break-down, an injury not unlike freezing injury in symptoms, sometimes develops after harvest in bulbs that have not been exposed to low temperatures. The scale tissue is discolored and water-soaked, and though more common on scales near the surface it may be found in deeper ones. The nature and cause of this injury is not known. It may be found in the market and in storage and may continue to develop during the storage period. For this reason it is likely to be confused with freezing injury, and it is, therefore, advisable to know the history of lots in question before final diagnosis is made.

CHEMICAL INJURIES

Blemishes of market onions which reduce their attractiveness are commonly encountered, especially in colored varieties. The color compounds in the scales are in the same general class as the chemist's color indicators, and therefore they respond accordingly to changes in acidity or alkalinity. A number of color blemishes occur that are caused by contact with alkaline materials. One of the most common of these is "alkali scorch" or "bag print." Dark-brown to black spots on yellow or red onions occur at points in which the bulbs come in contact with the jute-bag container, particularly if the bag has become moistened after being packed. Alkaline materials infiltrated in some bags are responsible for this. They occur in some lots of bags and not in others.

Another reaction of the same type is sometimes encountered in cold storage where leakage of ammonia fumes results in alkaline reaction of moisture on the surface of colored bulbs. Less than 1 percent of ammonia in the storage-room air will cause marked discoloration. A similar effect has been noted on stock covered with manure for protection from frost, in which case ammonia fumes arise from the manure. In all these cases the strength of the material, the amount of moisture on the bulb surface, and the duration of the exposure determine the extent of the injury.

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